

A Pilot Training Manual for the Terminal Configured Vehicle Electronic Attitude Director Indicator

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INTRODUCTION

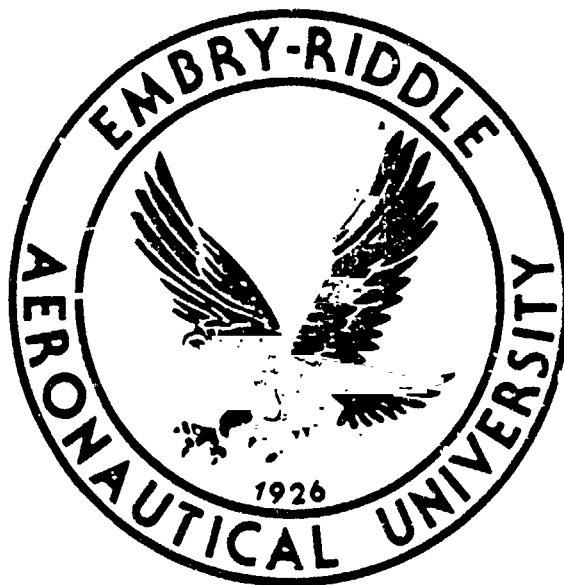
This manual presents a training course for the Terminal Configured Vehicle Electronic Attitude Director Indicator (EADI). This manual is a hardcopy version of a 28-minute, 90-slide audio-visual program which provides the basic instructional format for the introduction to the EADI and the strategy for learning the EADI symbology and their interpretation. The basic strategy is to start with known symbols, then add the new symbols with emphasis appropriate to their complexity and frequency of use. Each page of this manual is divided into two parts. The upper half of the page is a reproduction of the slide, and the bottom half contains the text associated with the slide, and is recorded on the audio tape.



National Aeronautics
and Space Administration

Terminal Configured Vehicle Program

This is the first in a series of presentations on electronic display systems currently being evaluated in the Terminal Configured Vehicle program at the National Aeronautics and Space Administration's Langley Research Center.



This presentation was developed and produced by the Aviation Research Center of Embry-Riddle Aeronautical University under the auspices of a NASA research contract. This contract is in direct support of the Terminal Configured Vehicle — TCV — Program office with technical guidance provided by the Analysis and Simulation Branch of the Langley Research Center.



The TCV Program is an advanced technology development activity designed to enable conventional transport aircraft to operate in reduced weather minima such as **Category Three**. These operations would occur in future high-density terminal areas equipped with new landing systems, navigational aids and increased air traffic control automation.

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Evaluation of:

I. New concepts in airborne systems:

a. avionics

b. air vehicle

II. Operational Flight Procedures

Within the scope of the TCV Program is the evaluation of new concepts in airborne systems, both avionics and the air vehicle, and operational flight procedures.

TCV Objectives

- 1. Reduce approach and landing accidents.**
- 2. Reduce weather minima requirements.**
- 3. Increase airport and airway capacity.**
- 4. Increase fuel efficiency.**
- 5. Reduce terminal area noise.**

More specifically, the TCV Program's objectives are to:

Reduce approach and landing accidents,
Reduce weather minima requirements,
Increase airport and airway capacity,
Increase fuel efficiency, and
Reduce terminal area noise.

1. Flight Control Systems

2. Pilot Display Systems

Two of the new concepts in the TCV Program deal with fly-by-wire flight control systems and electronic pilot display systems.

Electronic Attitude Director Indicator

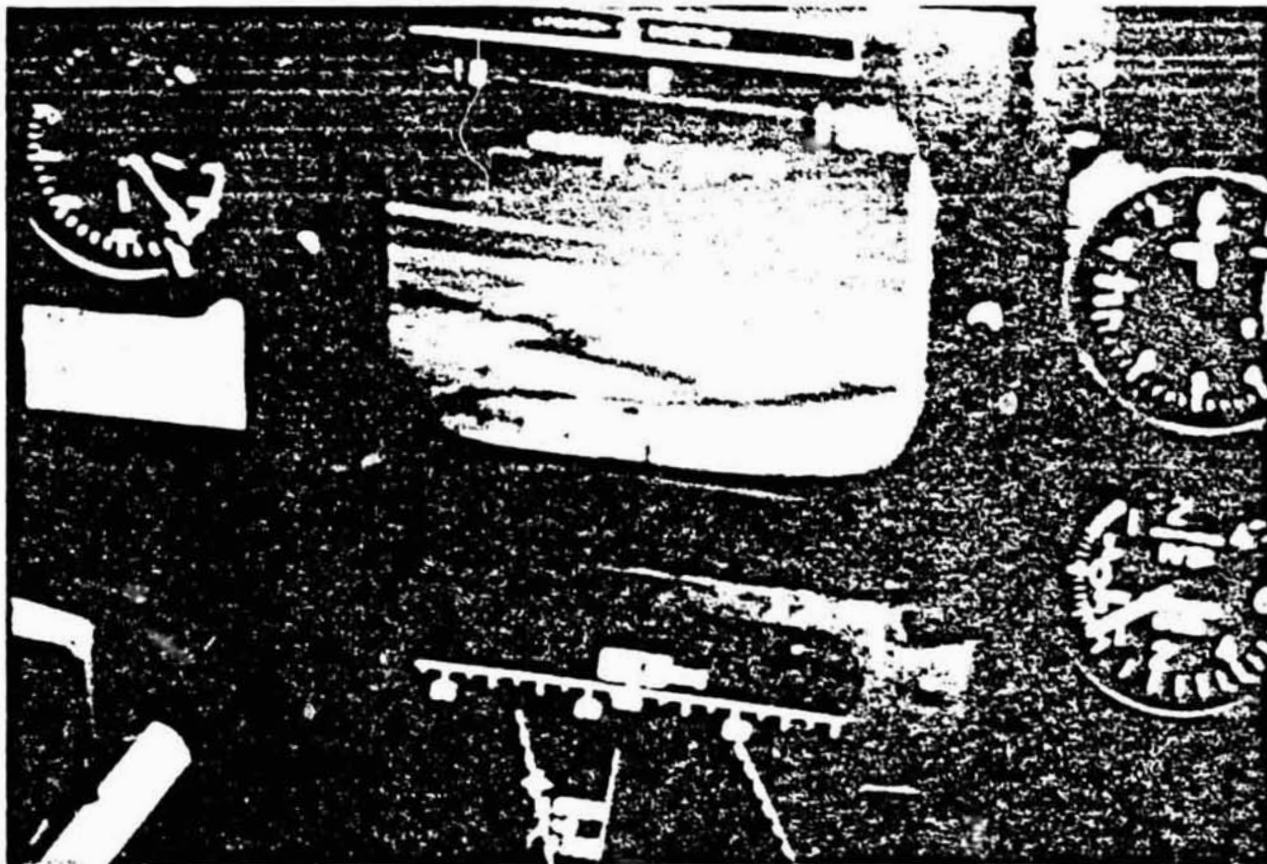
This presentation will introduce you to one of these electronic display systems — The Electronic Attitude Director Indicator — referred to as the EADI.

Identify and Interpret the EADI's Symbols.

Upon completion of this slide presentation, you will be able to correctly identify and interpret each symbol on the EADI,

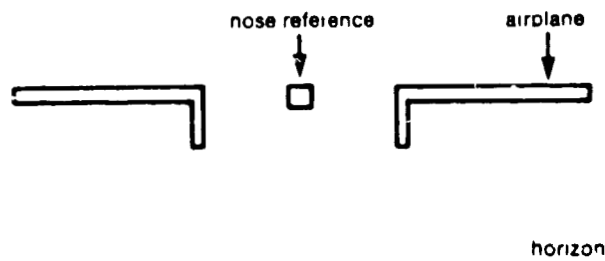
Relate EADI display to aircraft control.

and correctly relate the EADI display to aircraft control.

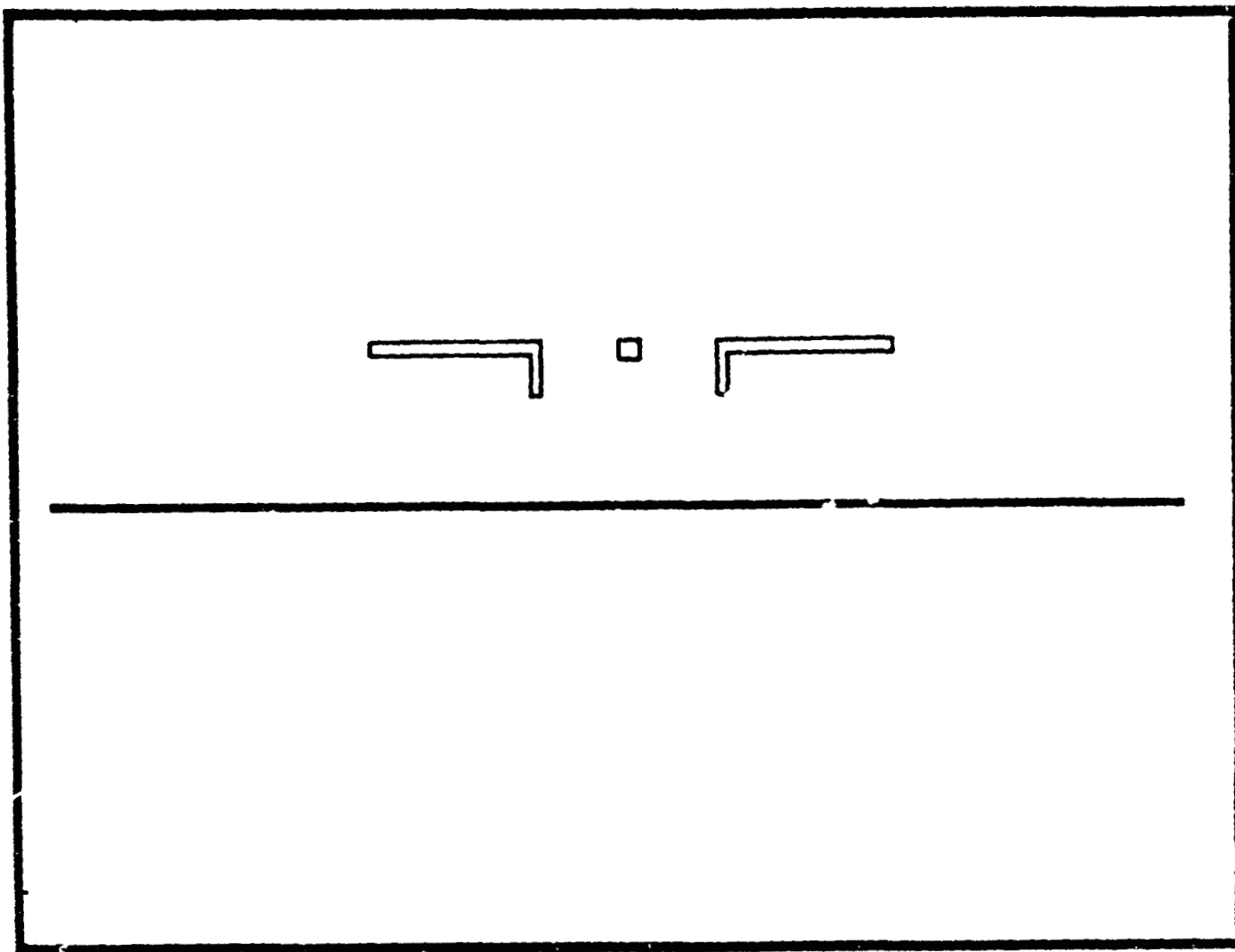


The Electronic Attitude Director Indicator (EADI), is the name given to the cathode ray tube or CRT, on which all of the symbols are displayed.

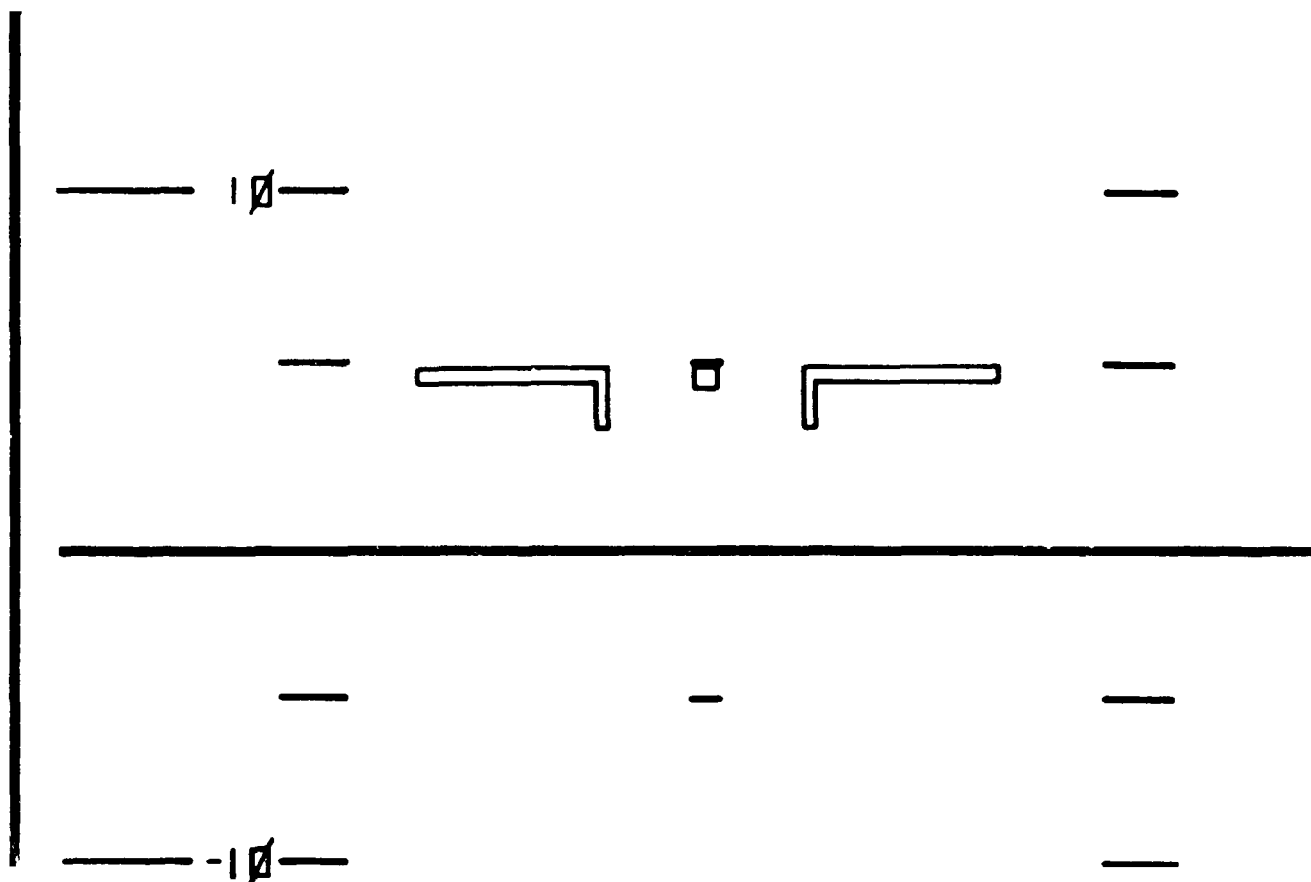
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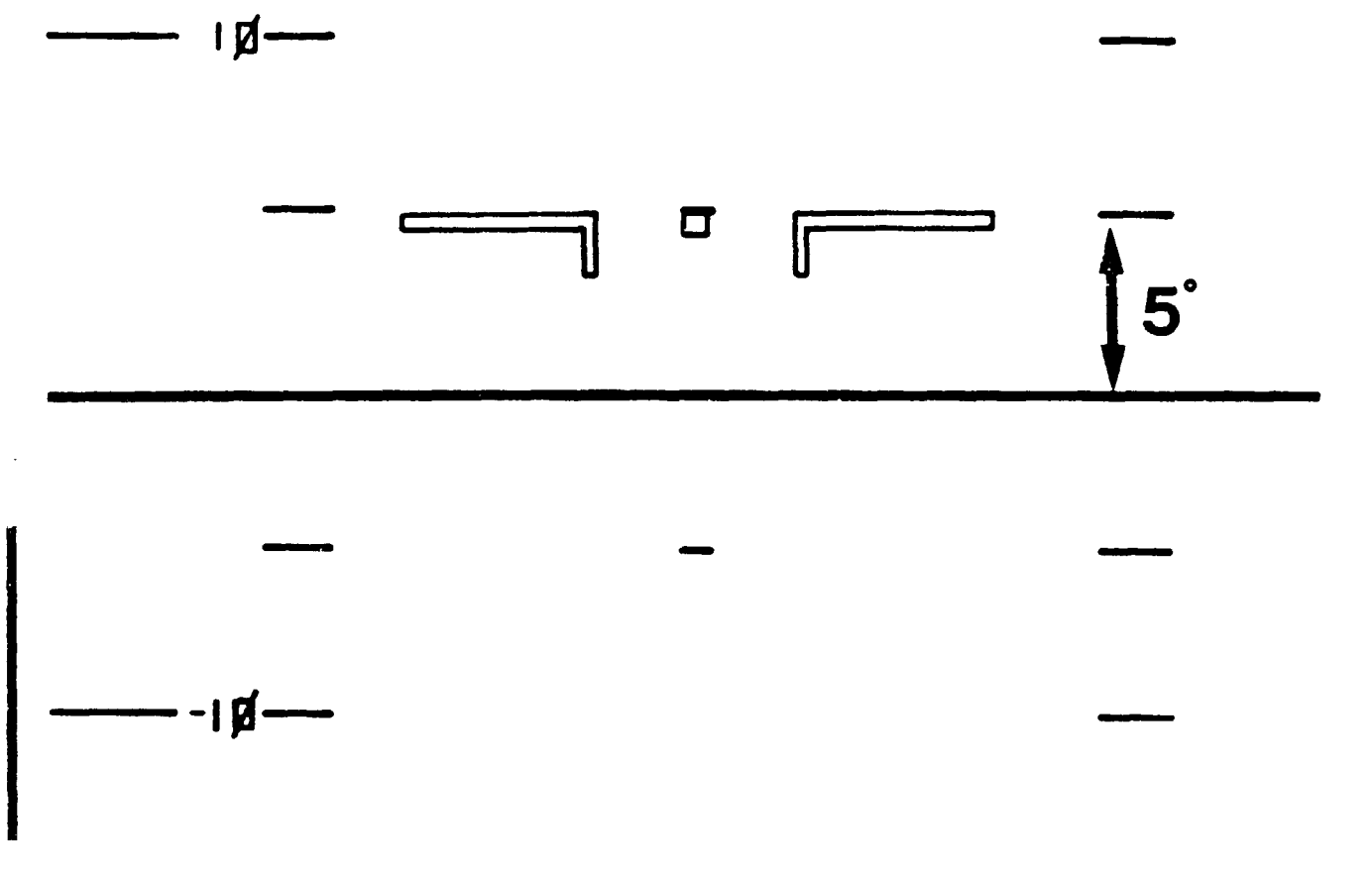
The EADI symbology provides the pilot with a wide range of information. Although many of the symbols will be new to you, we'll start with two of them that you are already familiar with: the horizon line and airplane symbol.



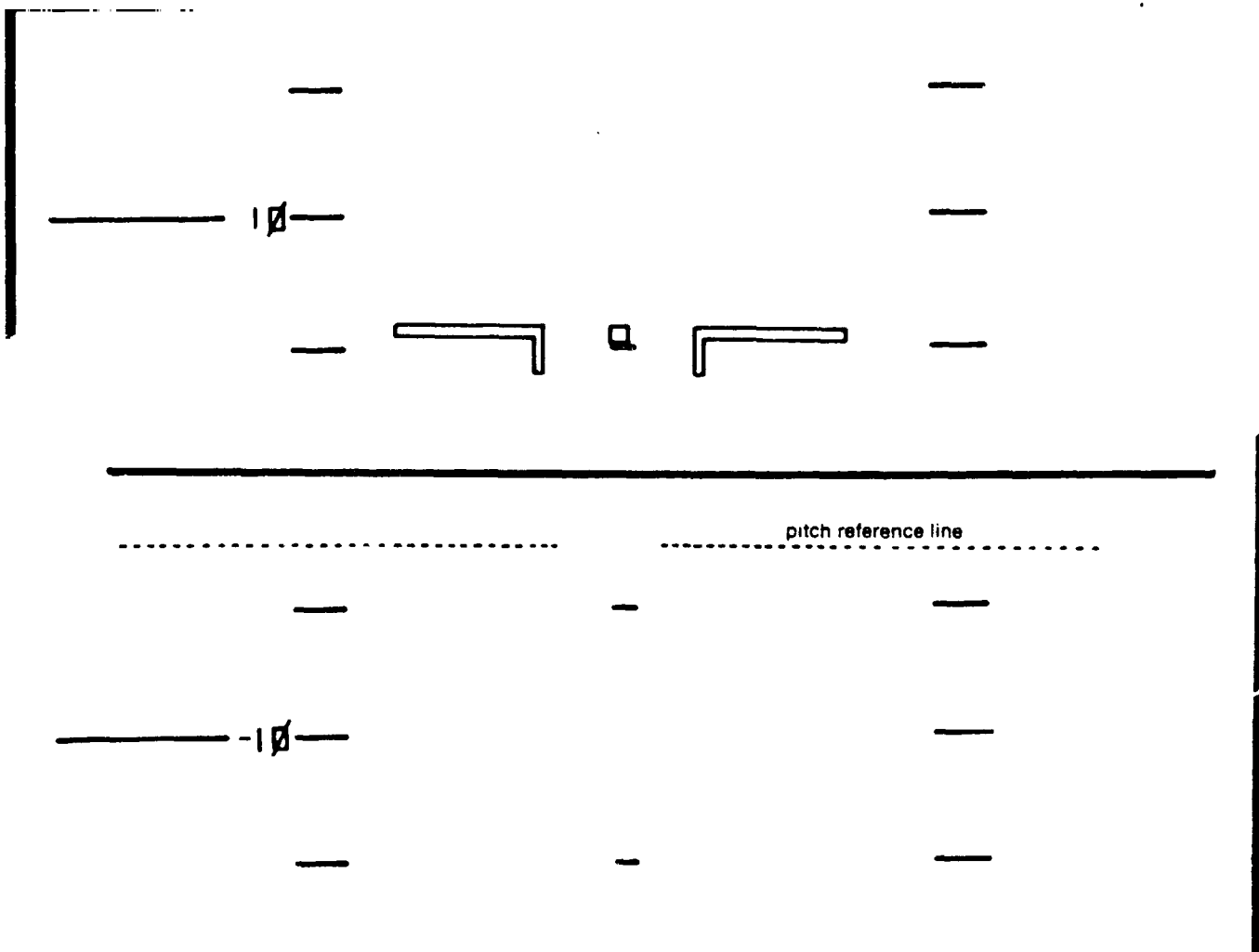
The reference for the interpretation of all symbols is the double width horizon line.



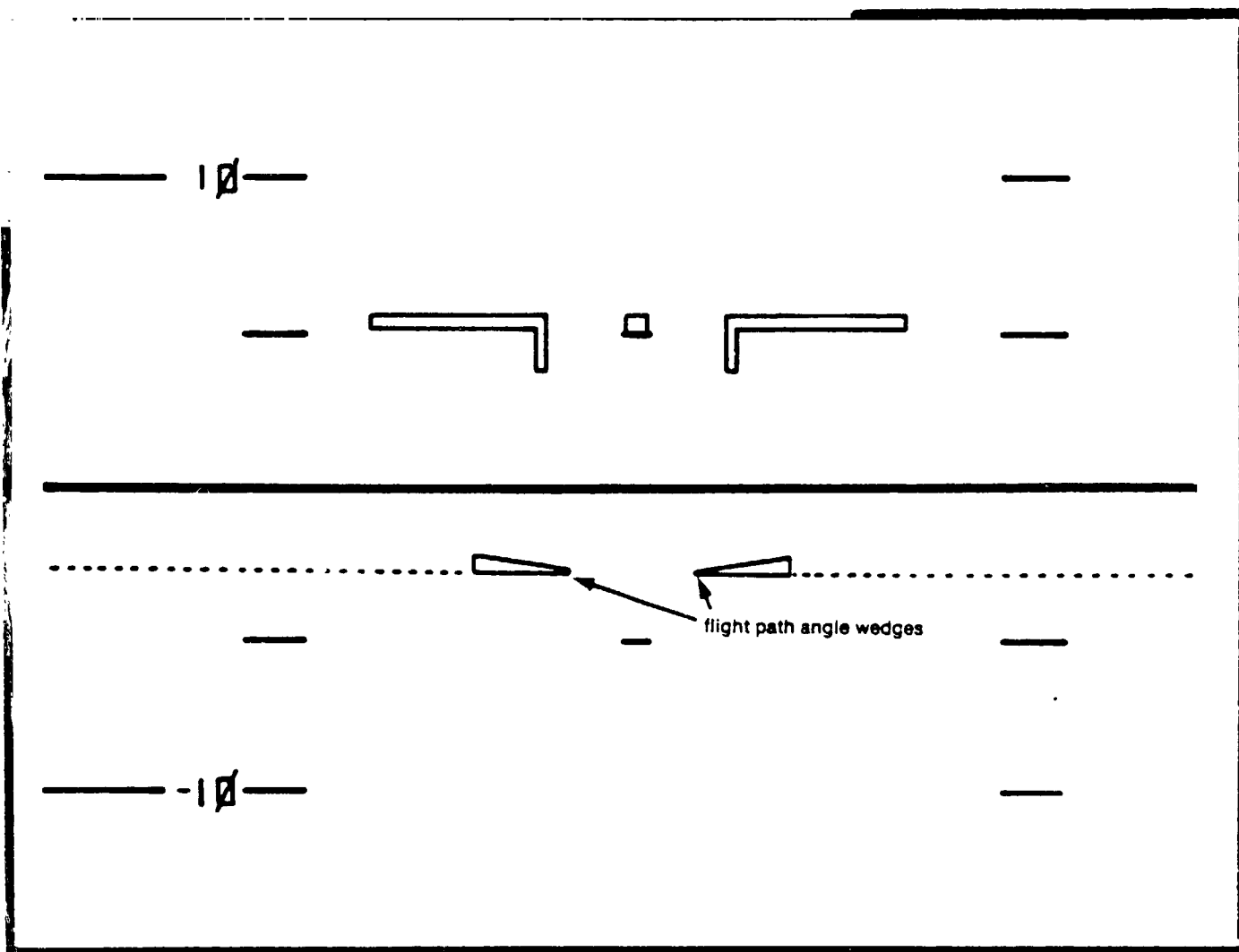
The pitch scale is a series of equally spaced lines relative to the horizon line. The horizon line is zero degrees pitch and the pitch scale lines represent 5 degree increments above and below the horizon line.



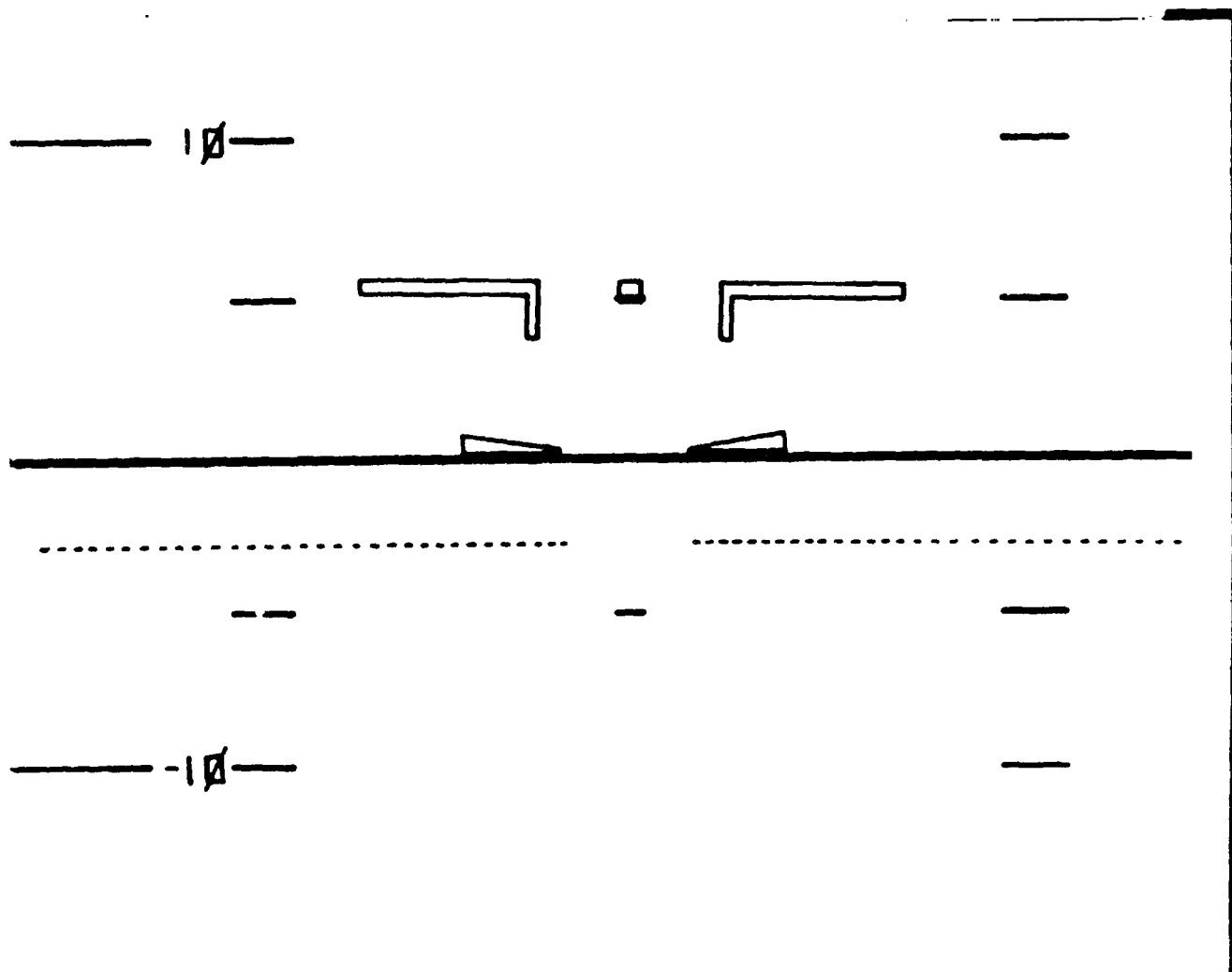
The airplane symbol, which consists of a representation of an airplane wing, landing gear, and a nose reference, is fixed in position on the EADI,...that is, all other symbols move in relation to it. The airplane symbol is biased up 5 degrees from the actual pitch attitude to unclutter the display.



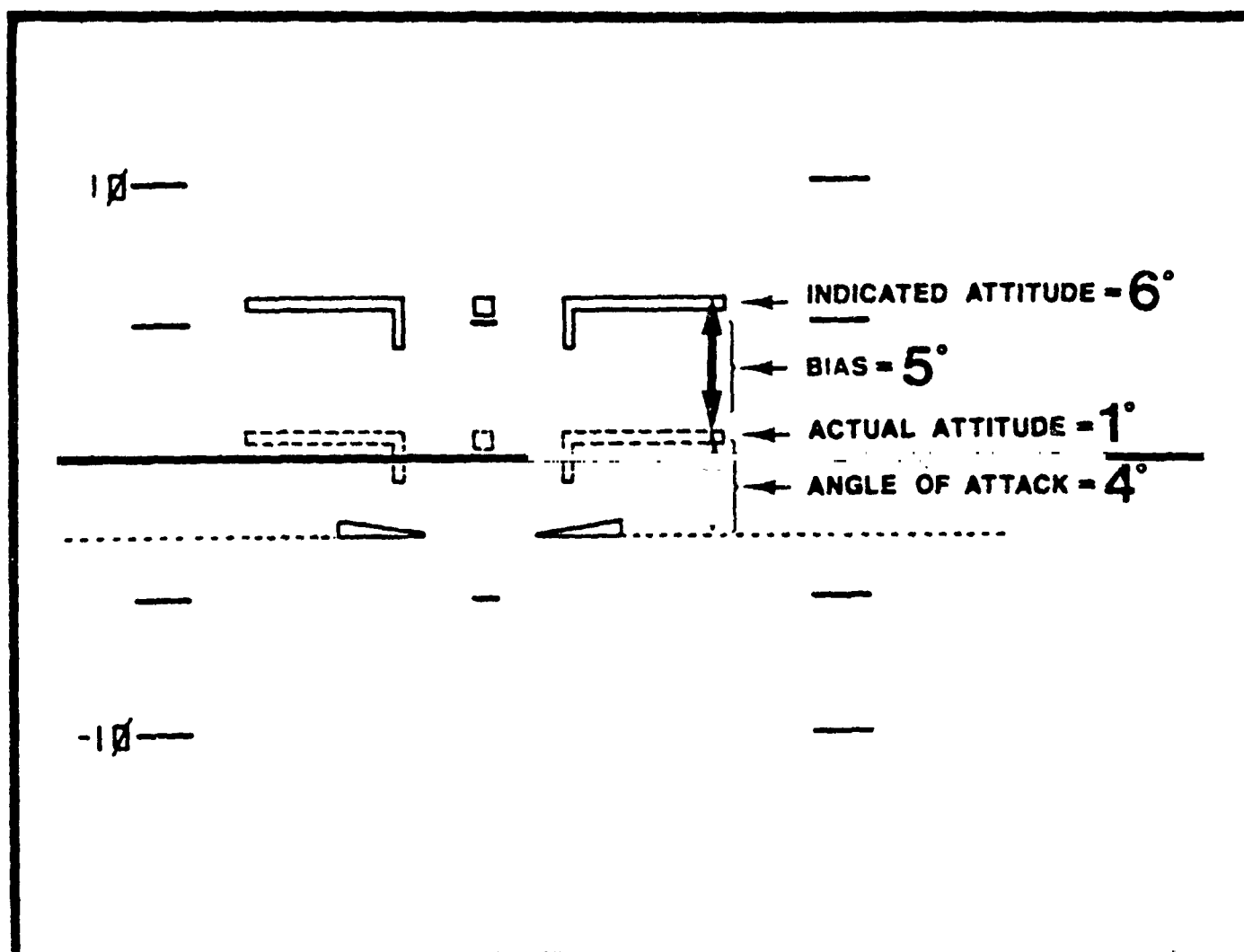
Now, here are the symbols that are central to the EADI, and to most of you, will be totally unfamiliar. A manually adjustable pitch reference line is provided. In this lesson, the dashed pitch reference line will be set at minus 3 degrees. This angle corresponds to many ILS glideslope angles.



The next important symbol is the flight path angle wedges. The wedges are provided to present both the current flight path angle and drift. This symbol is very important to the interpretation and use of the EADI.



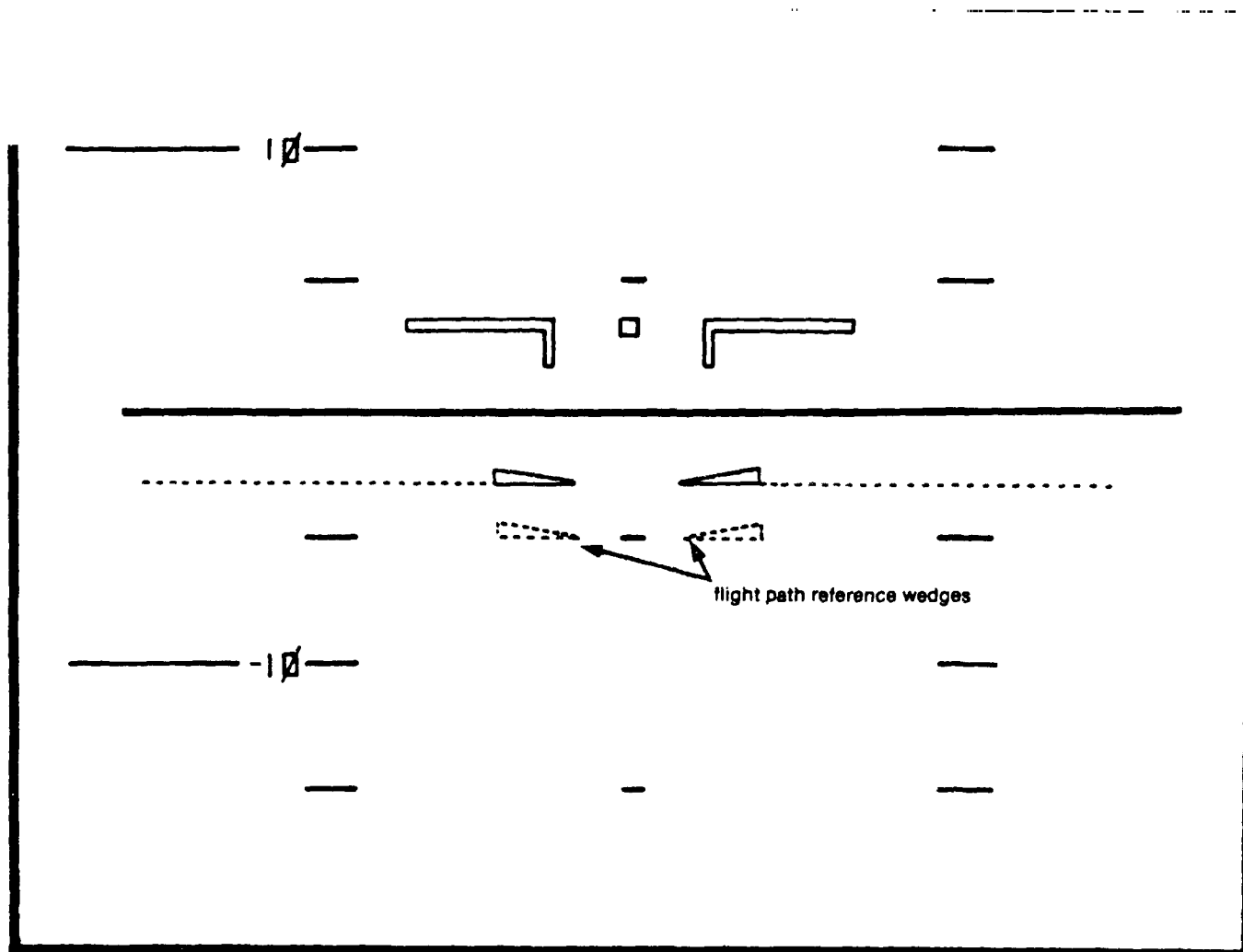
The flight path angle wedges will always be parallel to the horizon. In this display, the flight path angle wedges are set at zero degrees and indicate straight and level flight.



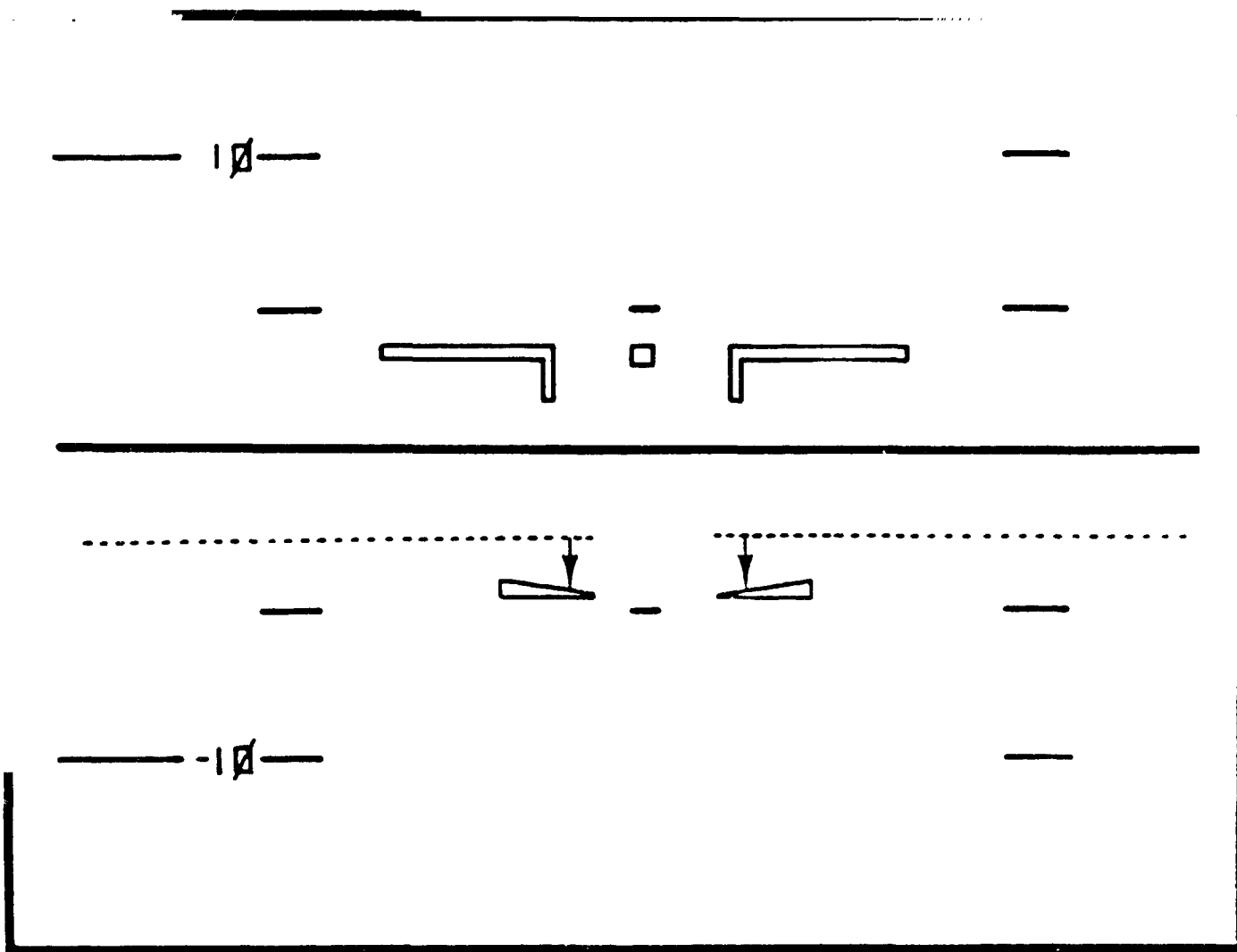
This display shows the flight path angle wedges at minus 3 degrees, indicating a descending path. Once again, let me emphasize the importance of the flight path angle wedges.

The flight path angle wedges also provide angle-of-attack information. The angle between the airplane symbol and flight path wedges is the angle of attack.

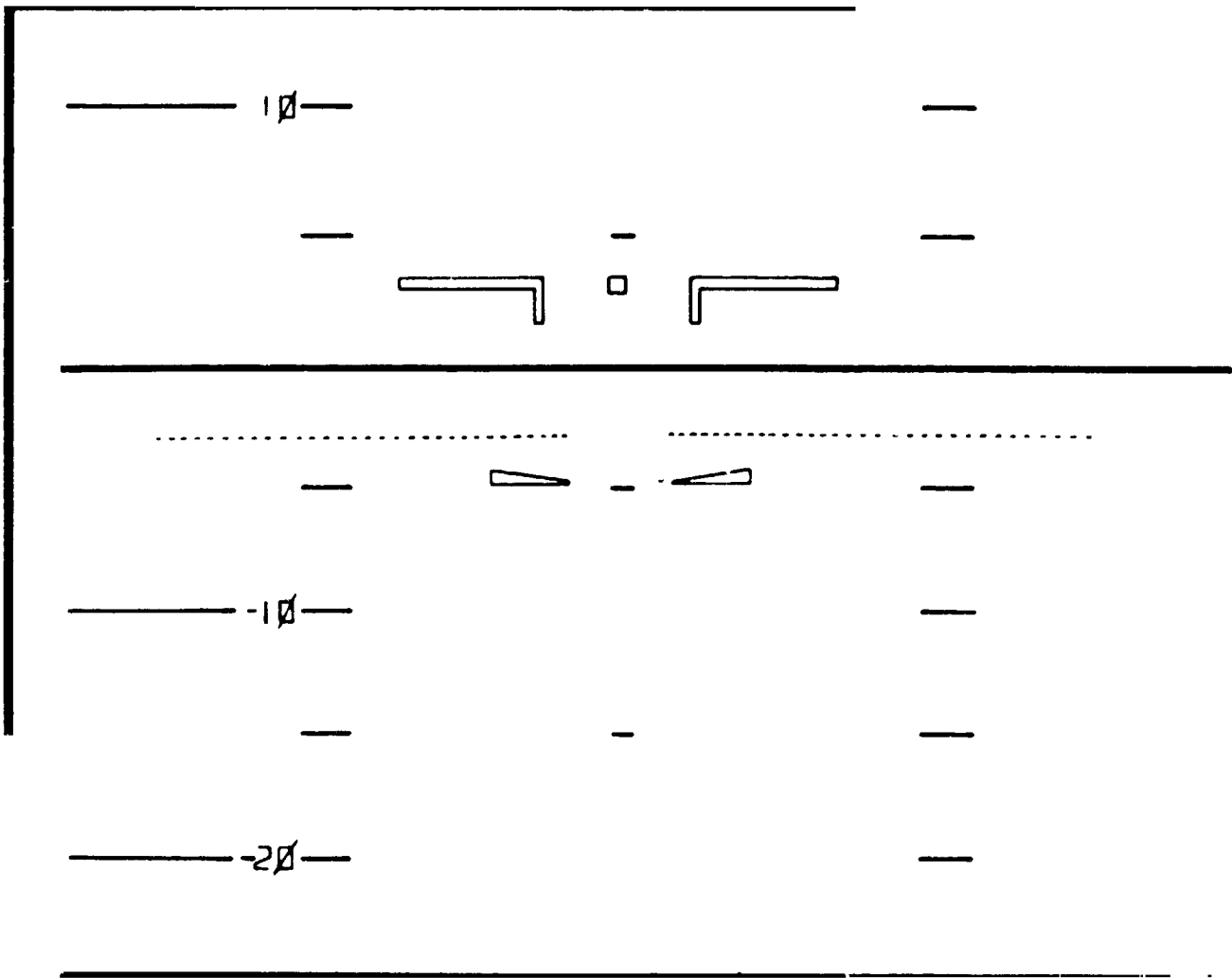
Remember for purposes of visual clarity in this lesson, the airplane's bias of 5 degrees up will also increase the displayed angle of attack by 5 degrees.



The dashed wedges symbol is the flight path angle reference symbol. The pilot can apply pressure on the control column to set the reference wedges at any desired flight path angle. In this display, the dashed reference flight path angle wedges are set at 5 degrees below the horizon, or minus 5 degrees.



When the pilot removes pressure from the Brolley Handles or the control column, the dashed reference wedges will remain in place and the flight path angle wedges will move to the commanded position.



The aircraft in this display is showing an aircraft at a flight path angle of minus 5 degrees.

Should you want to change the aircraft's flight path to minus 3 degrees, ...

————— 1° —————



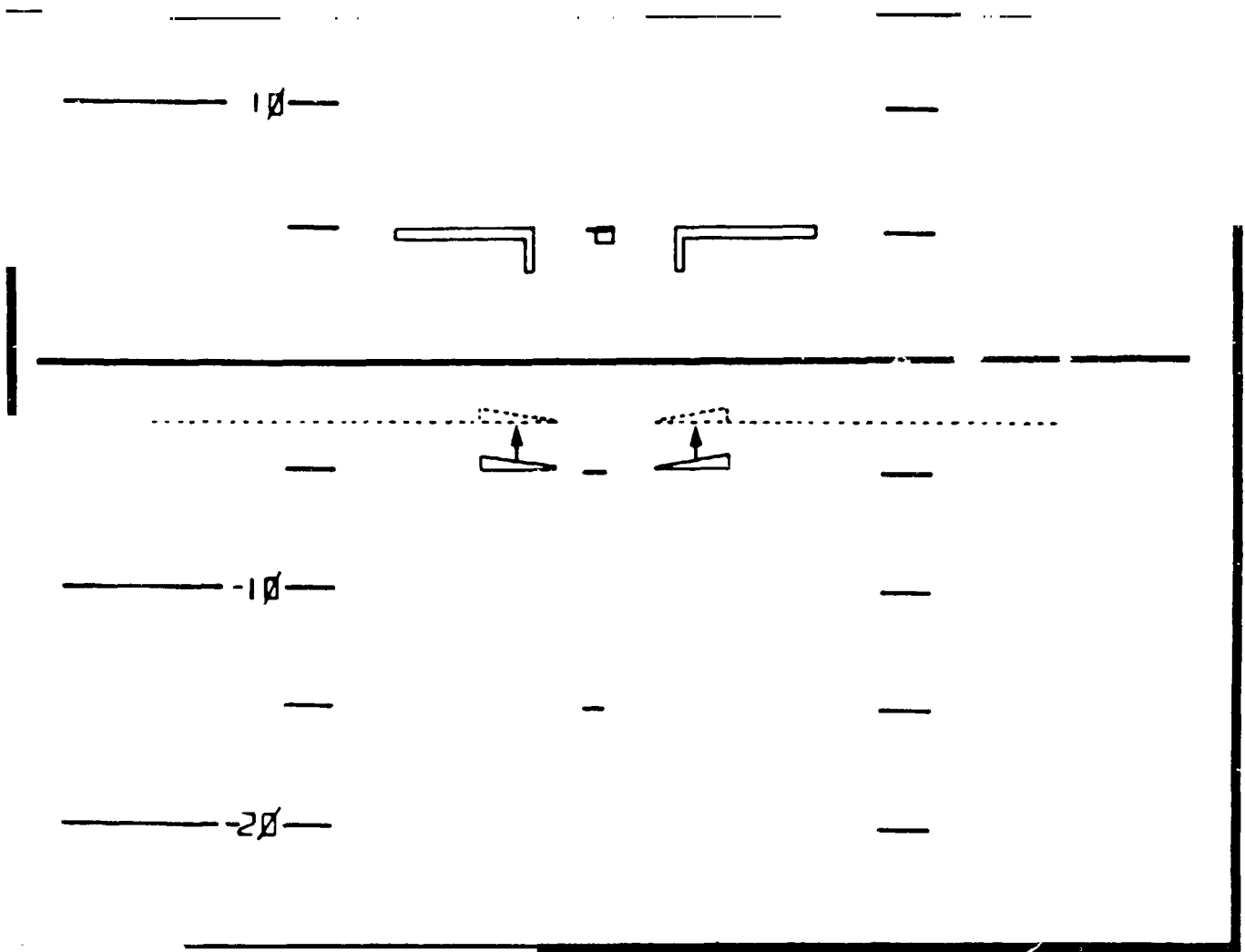
————— -1° —————



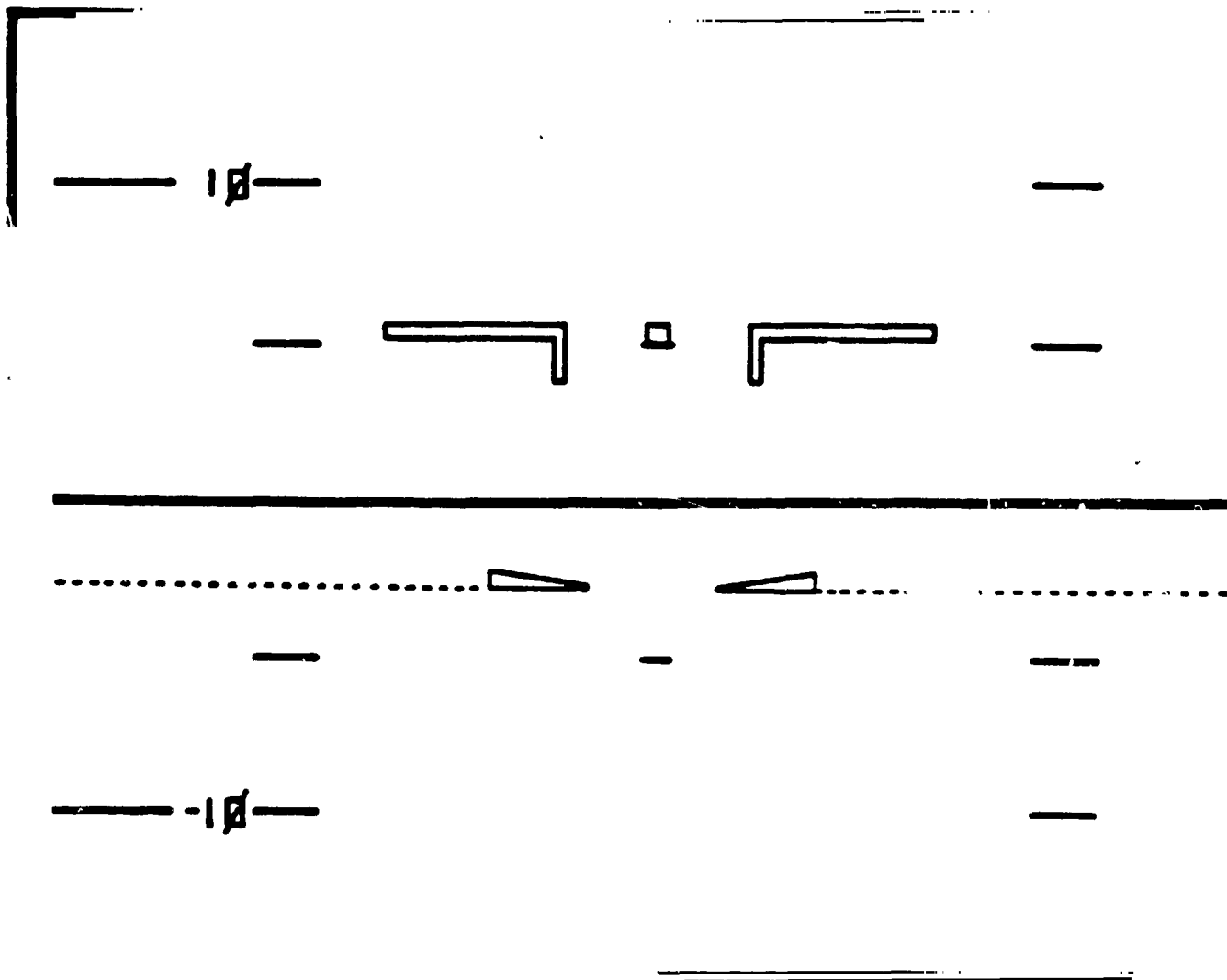
————— -2° —————



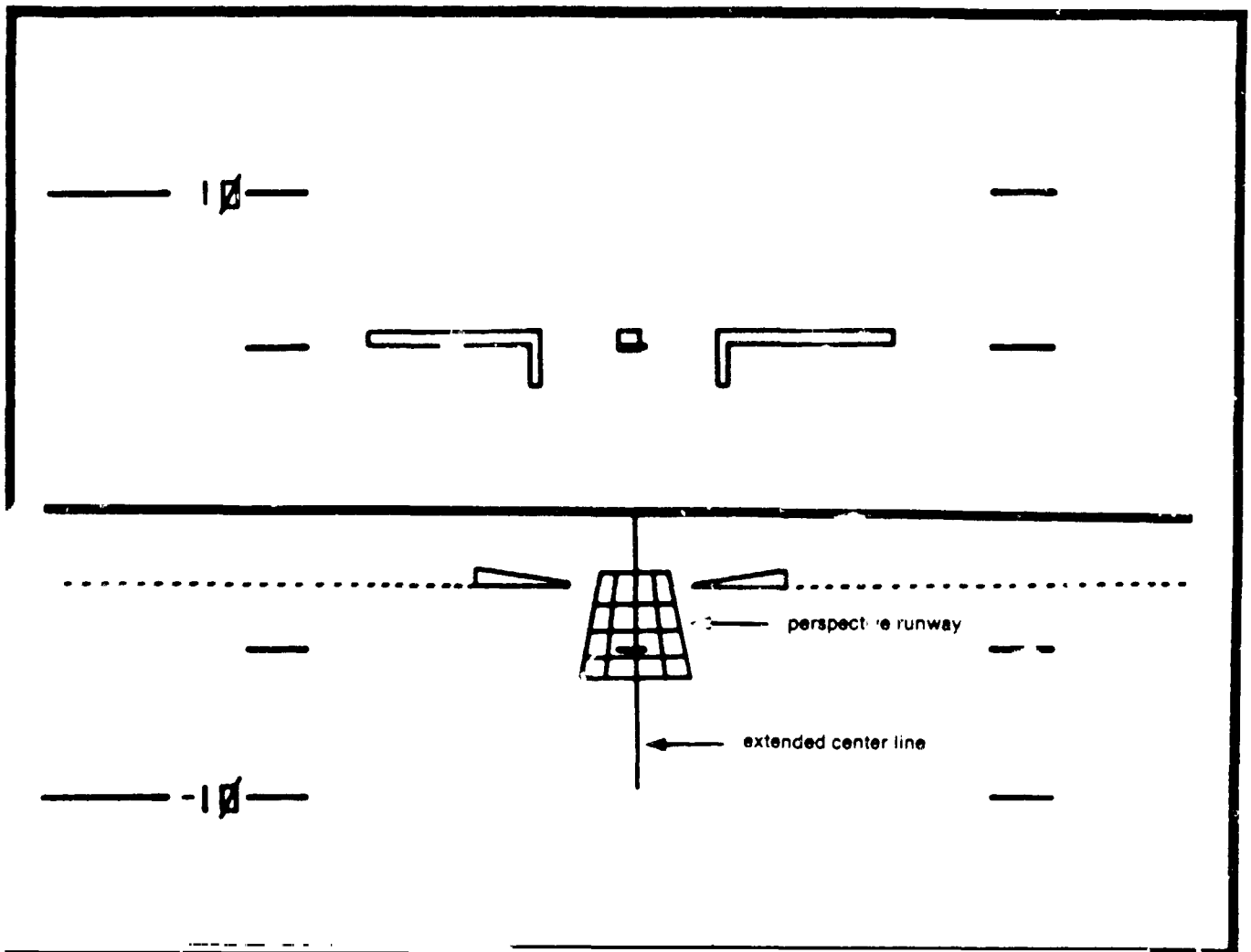
simply move the flight path angle reference wedges to the minus 3 degree position and release the control wheel. The flight computer will rapidly respond and your new flight path will be minus 3 degrees.



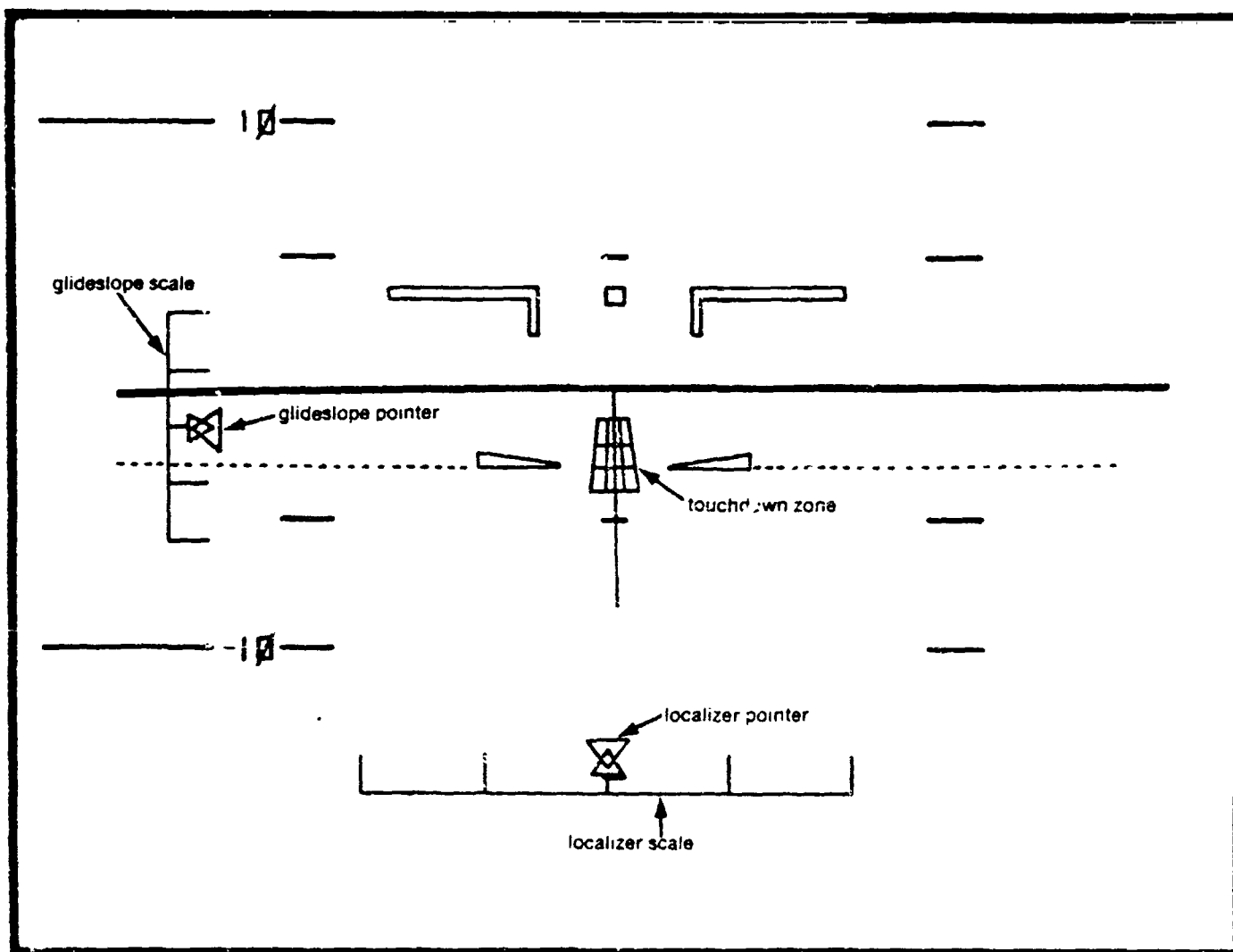
This will be indicated on the EADI by the flight path angle wedges moving to overlay the reference wedges.



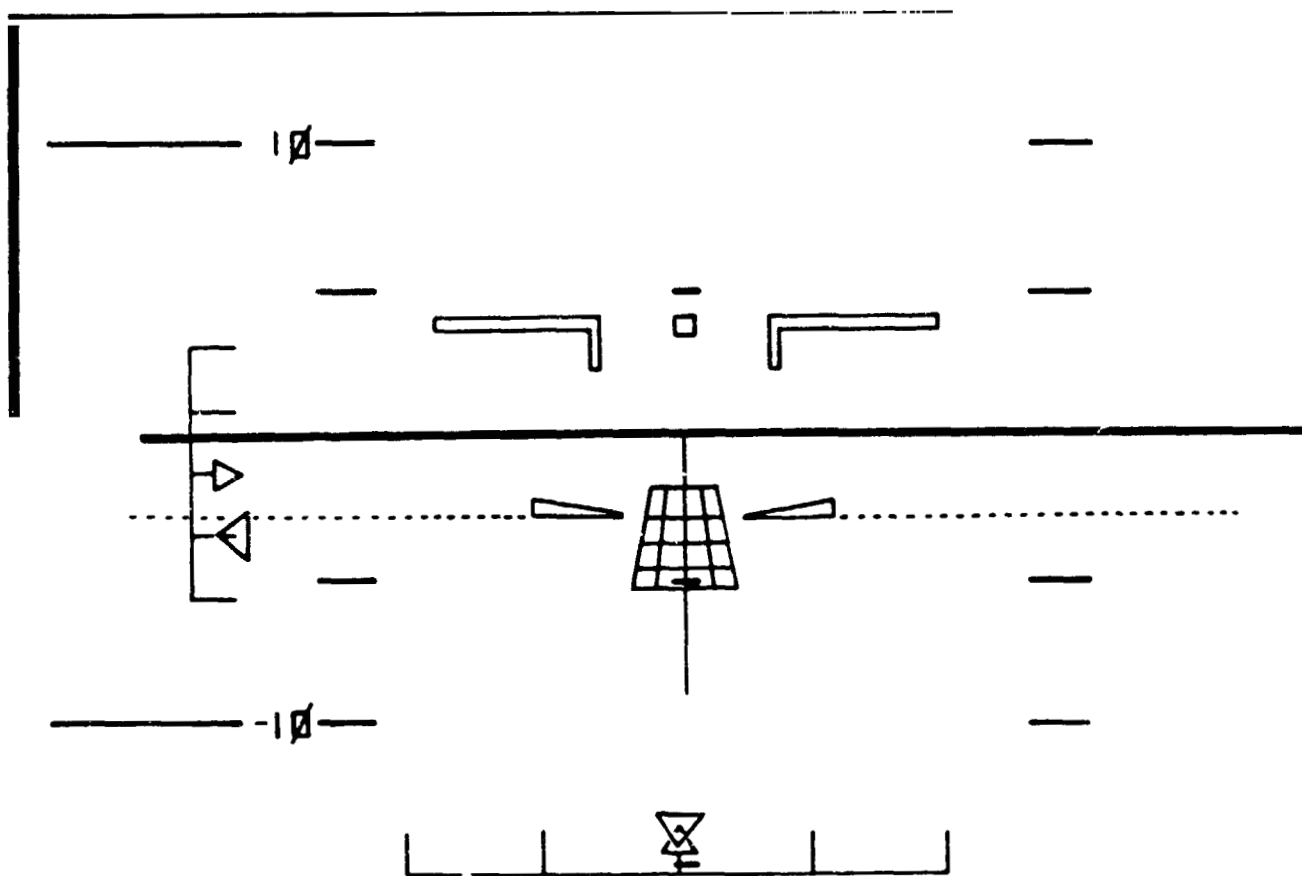
The aircraft is now on a minus 3 degree flight path.



A perspective runway and extended centerline symbol provide a visual indication of the aircraft's relationship to the actual runway.



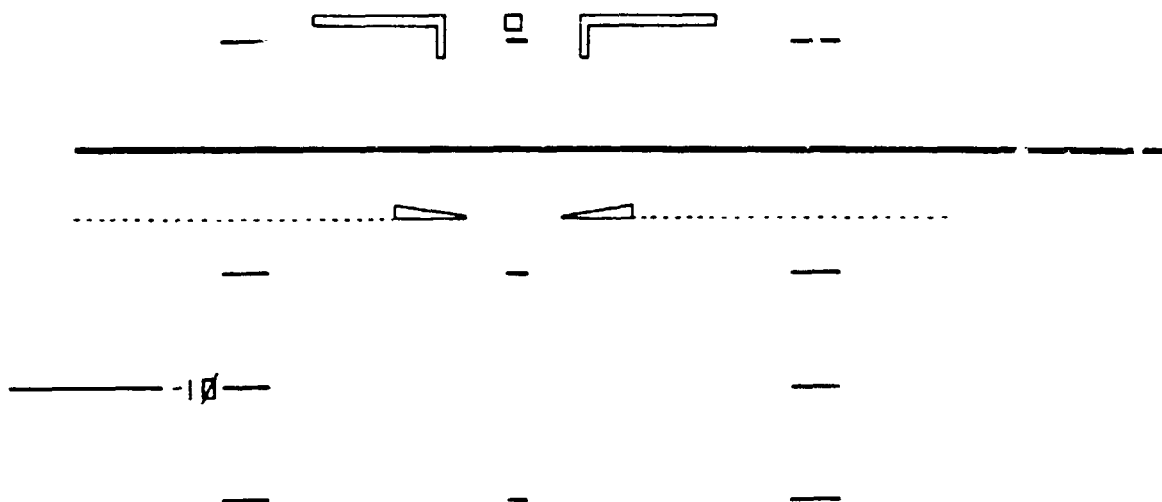
Standard ILS glideslope and localizer information is provided. The Localizer Scale is on the bottom of the display, and, the glideslope is along the left edge. Both pointers are shown centered; that is on localizer; on glideslope. When the pitch reference line is set to the airport's glideslope angle and the flight path angle wedges are on this reference line, they will point to the touchdown zone. Note that the touchdown zone is the first horizontal line beyond the runway threshold.



This display shows the aircraft on the localizer but above glideslope. Note that the flight path angle wedges indicate an aim point long on the runway, and the aircraft is 1 dot" high.

QUIZ

Now, let's have a short, informative quiz of the symbols covered so far. Make certain that you have your test sheet or a piece of paper and pencil handy. Here's the first question:



What is the aircraft's actual pitch attitude?

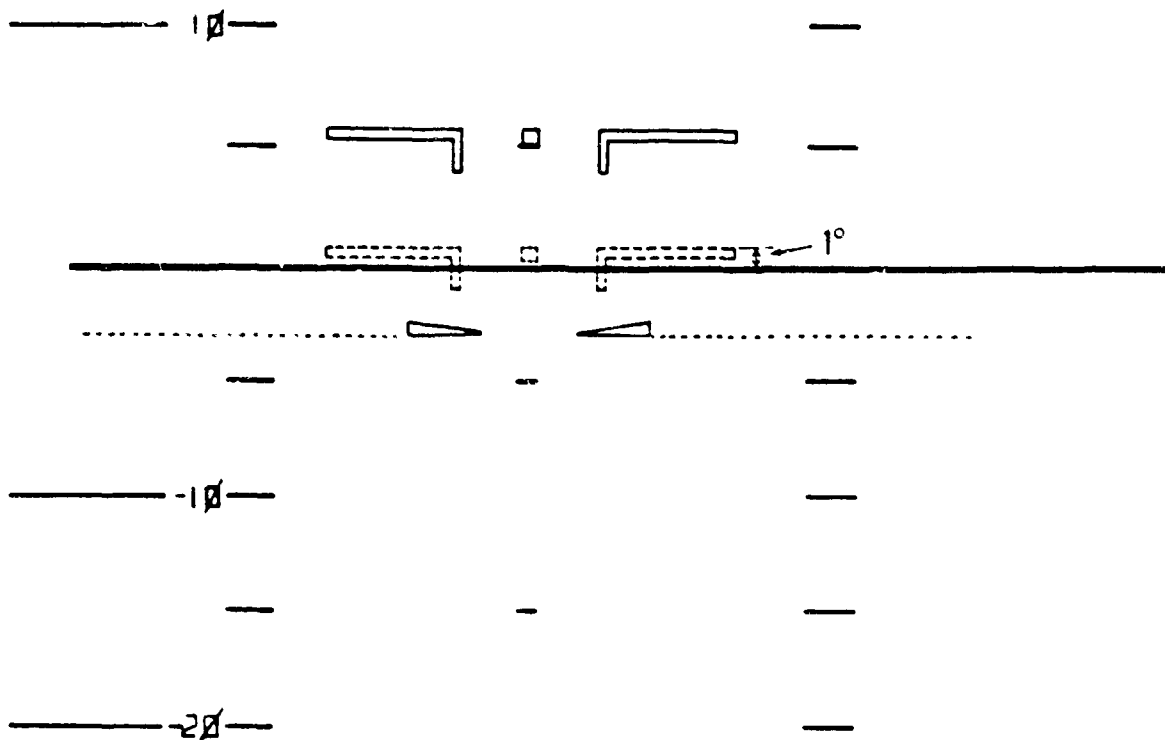
- A. 6 degrees**
- B. 1 degree**
- C. minus 3 degrees**

After you've chosen your answer, re-start the tape.

Recalling that we have biased the location of the aircraft symbol for visual clarity, what is the aircraft's actual pitch attitude?

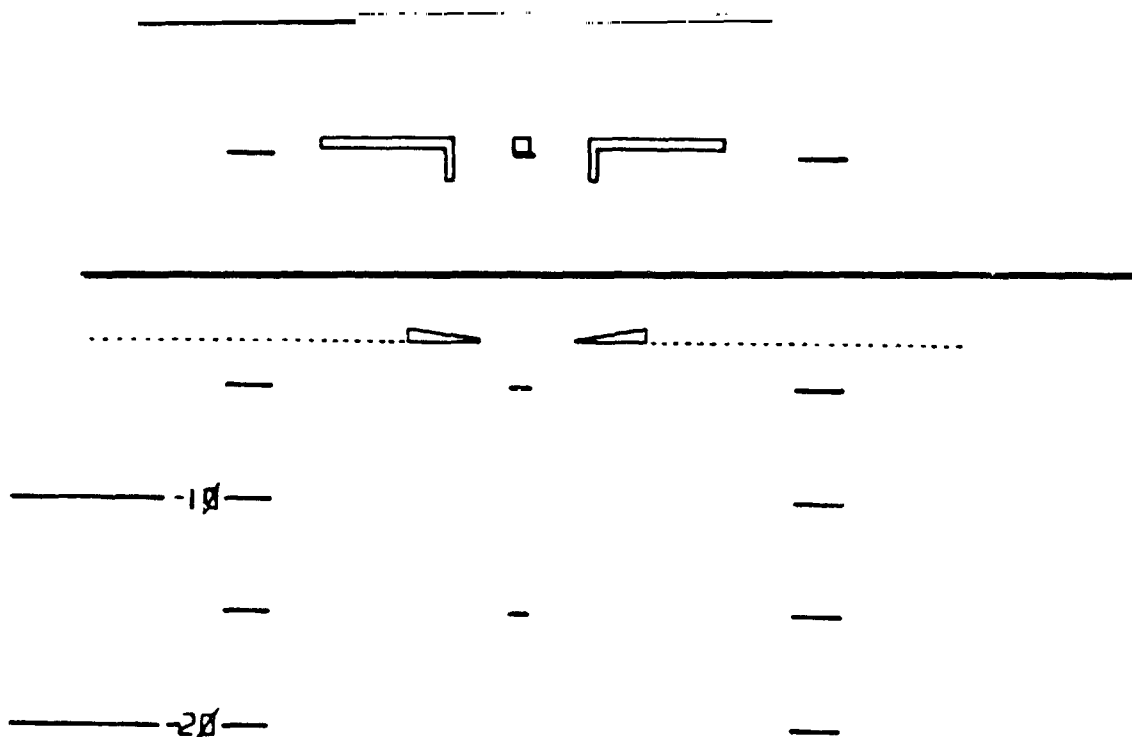
- A. 6 degrees
- B. 1 degree
- C. minus 3 degrees?

Restart the tape when you've chosen your answer.



B. 1°

The correct answer is 1° . Once again, the airplane symbol is electronically biased 5° to allow for greater visibility of other symbols that will appear on or near the horizon line.



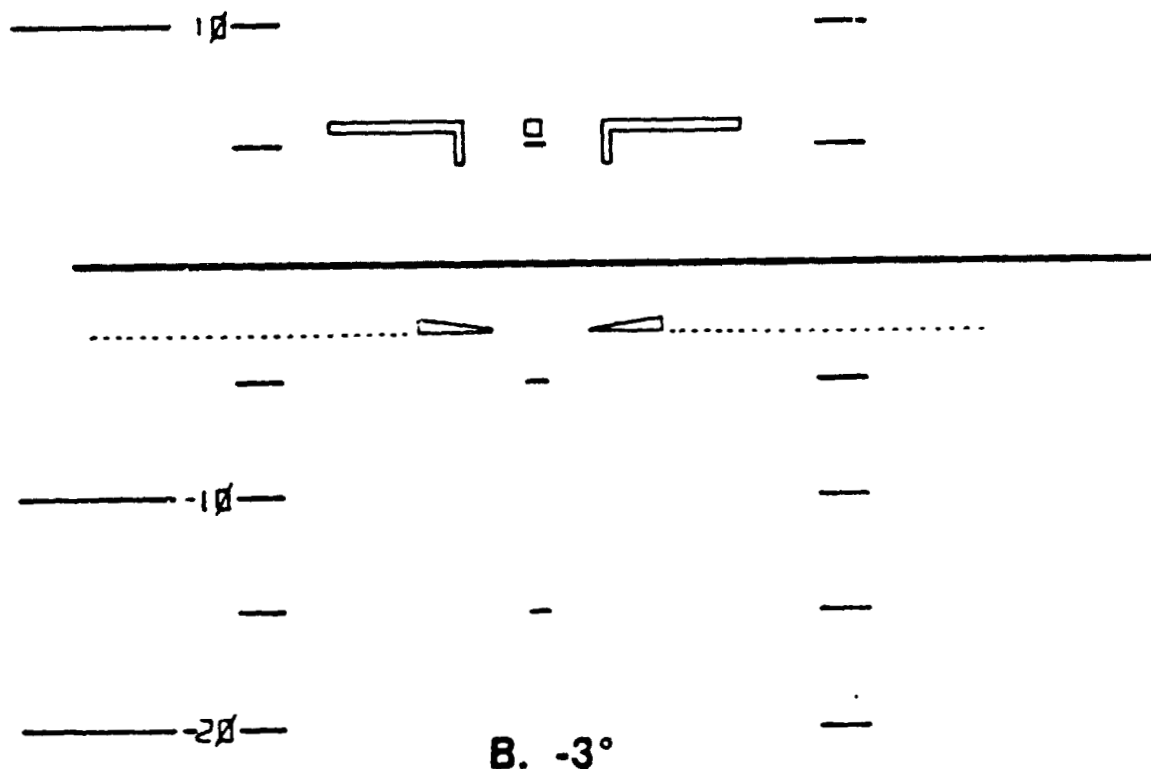
The flight path angle is:

- A. 0°**
- B. -3°**
- C. -5°**

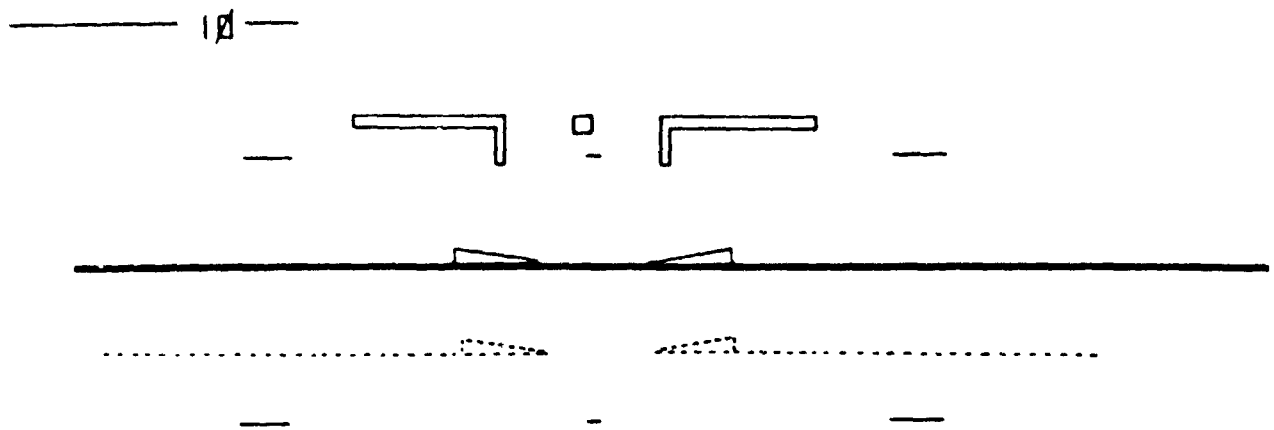
Next question...the flight path angle is:

- A. 0°
- B. -3°
- C. -5°

Restart the tape when you've chosen your answer.



The correct answer is minus 3 degrees. The flight path angle wedges are aligned with the dashed pitch reference line located at 3 degrees below the horizon line. This is referred to as minus 3 degrees on the pitch scale.



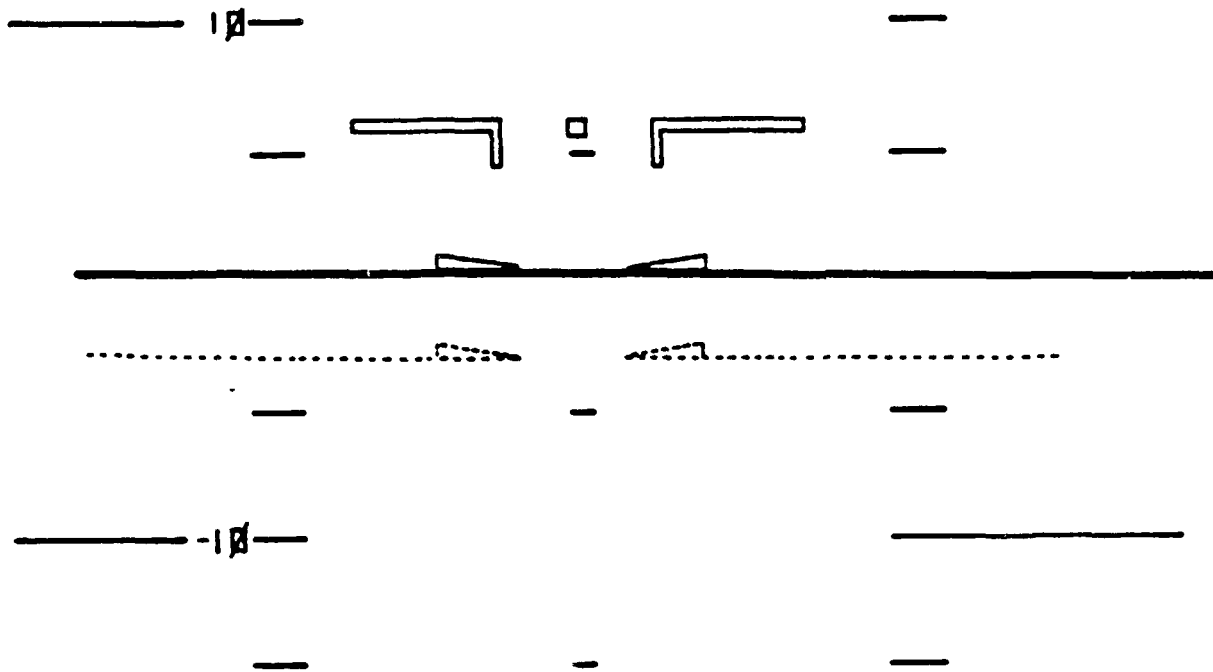
Which is correct?

- A. descending flight path of -3°**
- B. descending at -3° and commanded to level off**
- C. A/C flying level and commanded descent at -3°**

Now here's the last question: Which of the following situations is correct?

- A. The aircraft is descending along a flight path of minus 3 degrees.
- B. The aircraft is descending at minus 3 degrees but is commanded to level off.
- C. The aircraft is flying level but is commanded to descend at minus 3 degrees.

Once again restart the tape after you've chosen your answer.



C. Aircraft flying level and commanded to descend at minus 3 degrees.

The correct answer is C.

The solid wedges represent the actual flight path angle...as shown here at 0° ,... level flight. The dashed wedges are the flight path angle reference commands,... here shown to be a minus 3 degree descent.

The flight control system and the auto throttles will now drive the solid wedges to the position shown by the dashed reference wedges and the aircraft's flight path will be adjusted accordingly.



Bank Information

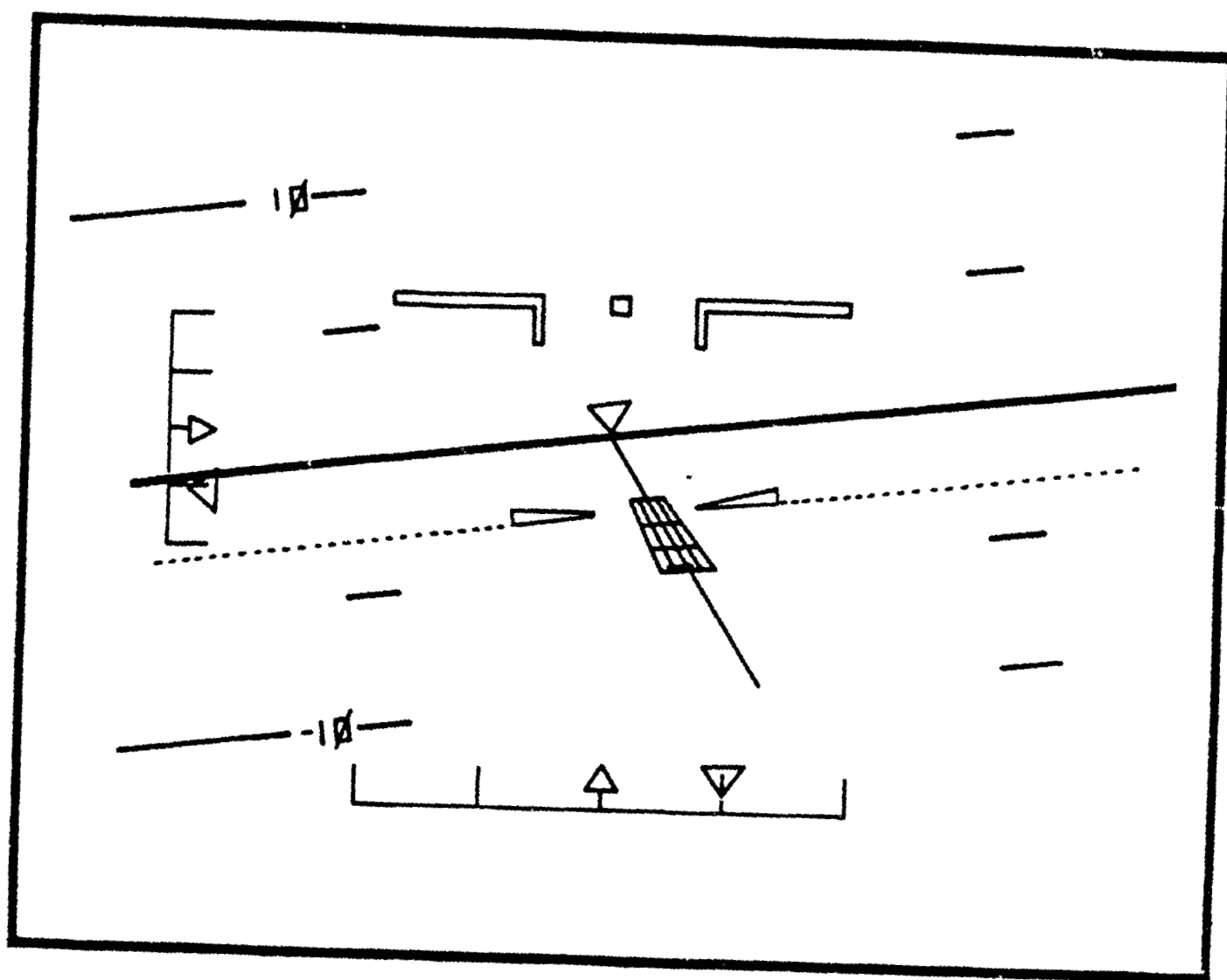
Airplane Symbol

Horizon Line

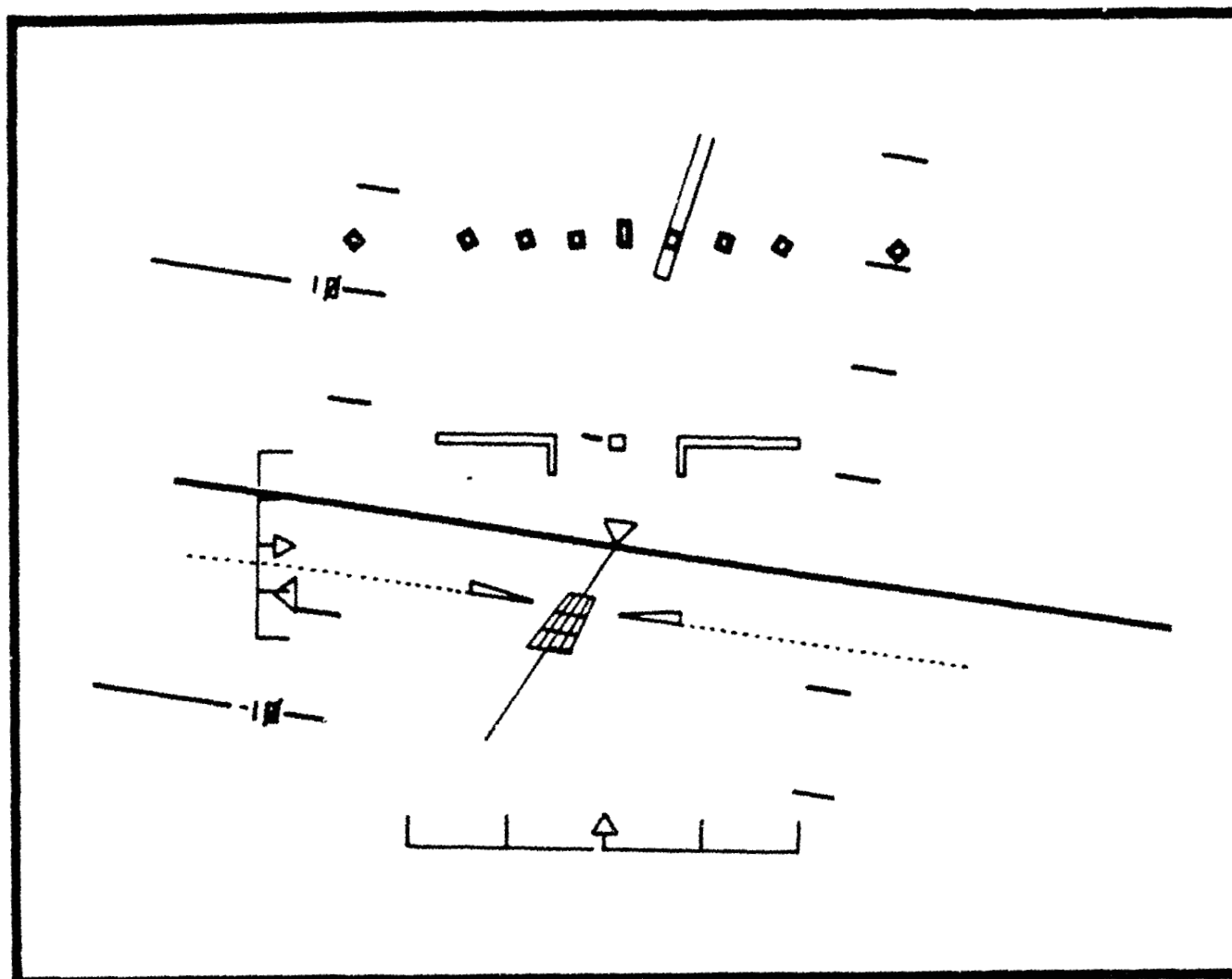
Bank Angle Scale

Bank Angle Pointer

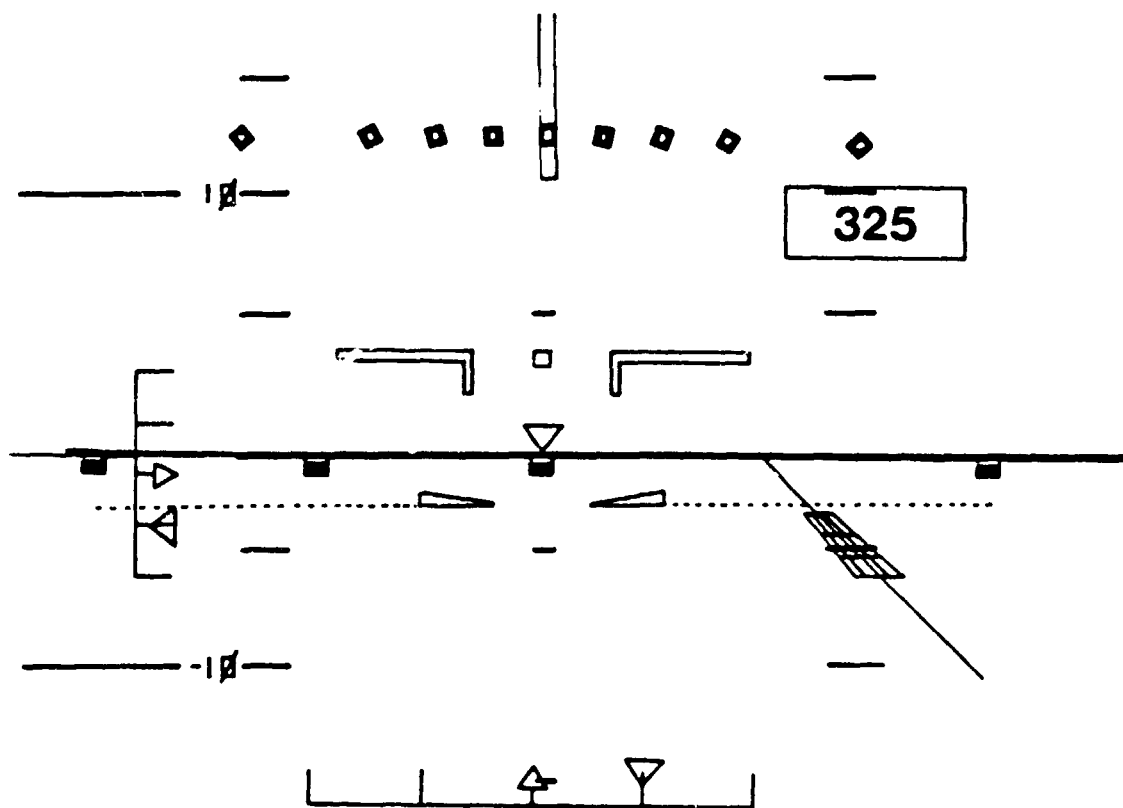
Next, let's cover the 4 symbols that provide bank information. They are the airplane symbol, horizon line, bank angle scale and bank angle pointer.



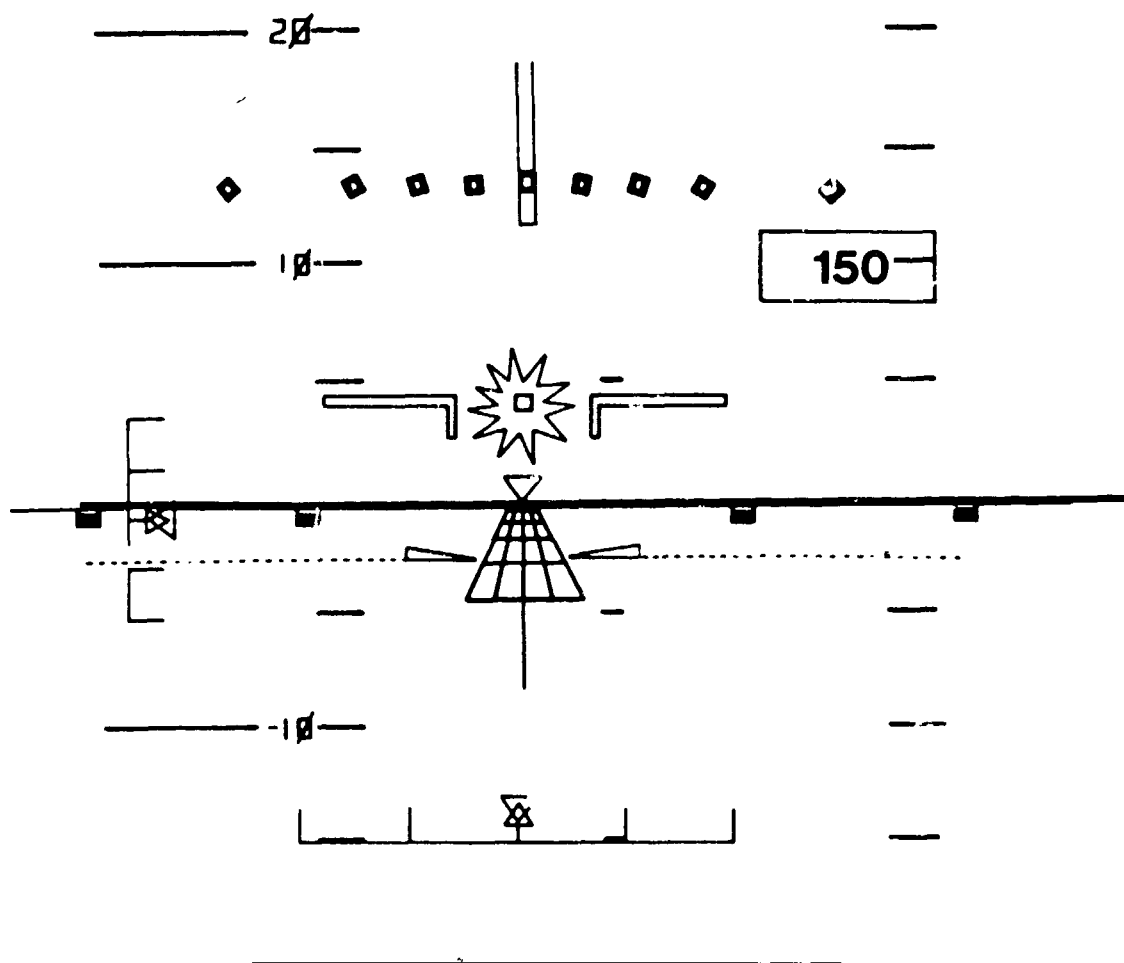
For immediate bank information we use the airplane symbol relative to the horizon line. A right bank is shown here.



For more precise bank angle information, the fixed bank angle scale and the movable bank angle pointer are used. Shown here is a 10° left bank.



The next symbol is the radar altitude. It is displayed in the window in the upper right hand corner. The window will remain blank until the aircraft is below 2 thousand 5 hundred feet above the ground.



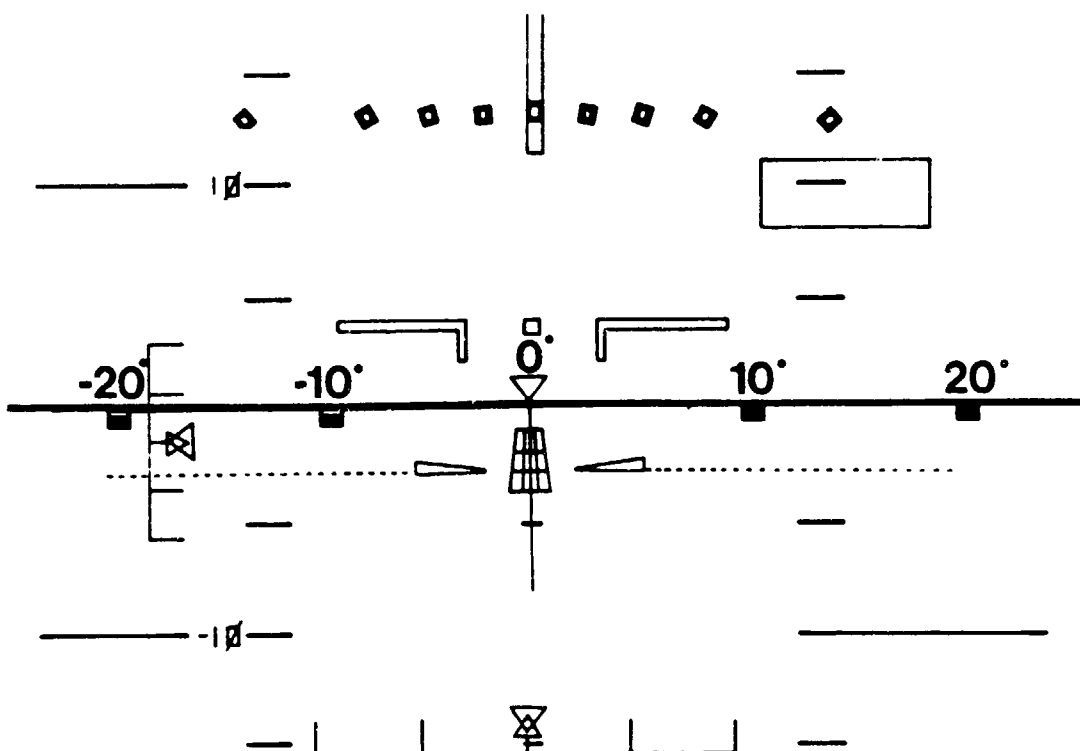
When the aircraft is below decision height, the nose reference symbol will start flashing.

Track Angle Information

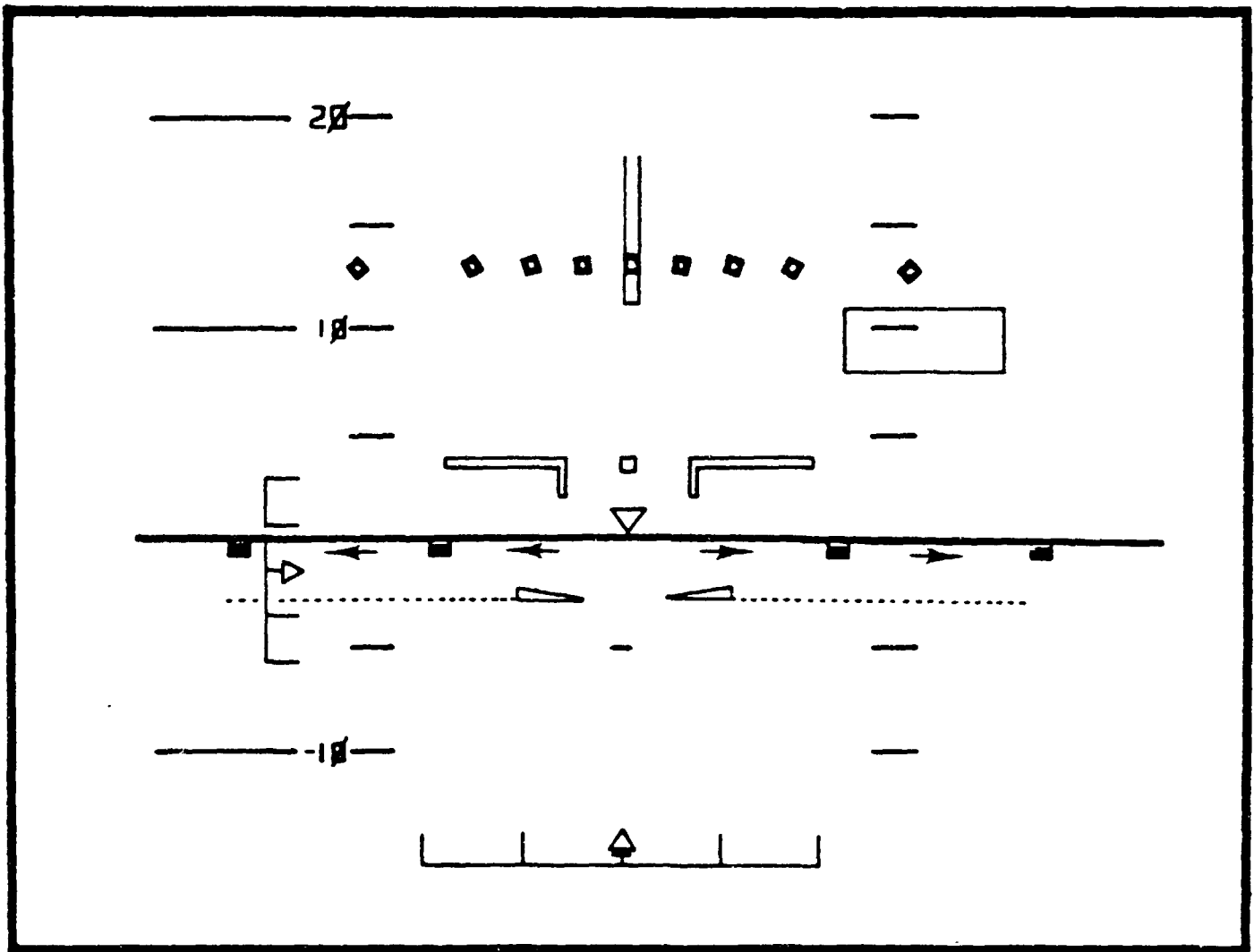
Track Angle Scale

Track Angle Pointer

Another unique feature of the EADI display system is track angle information. This information is provided by two symbols: the track angle scale and the track angle pointer.

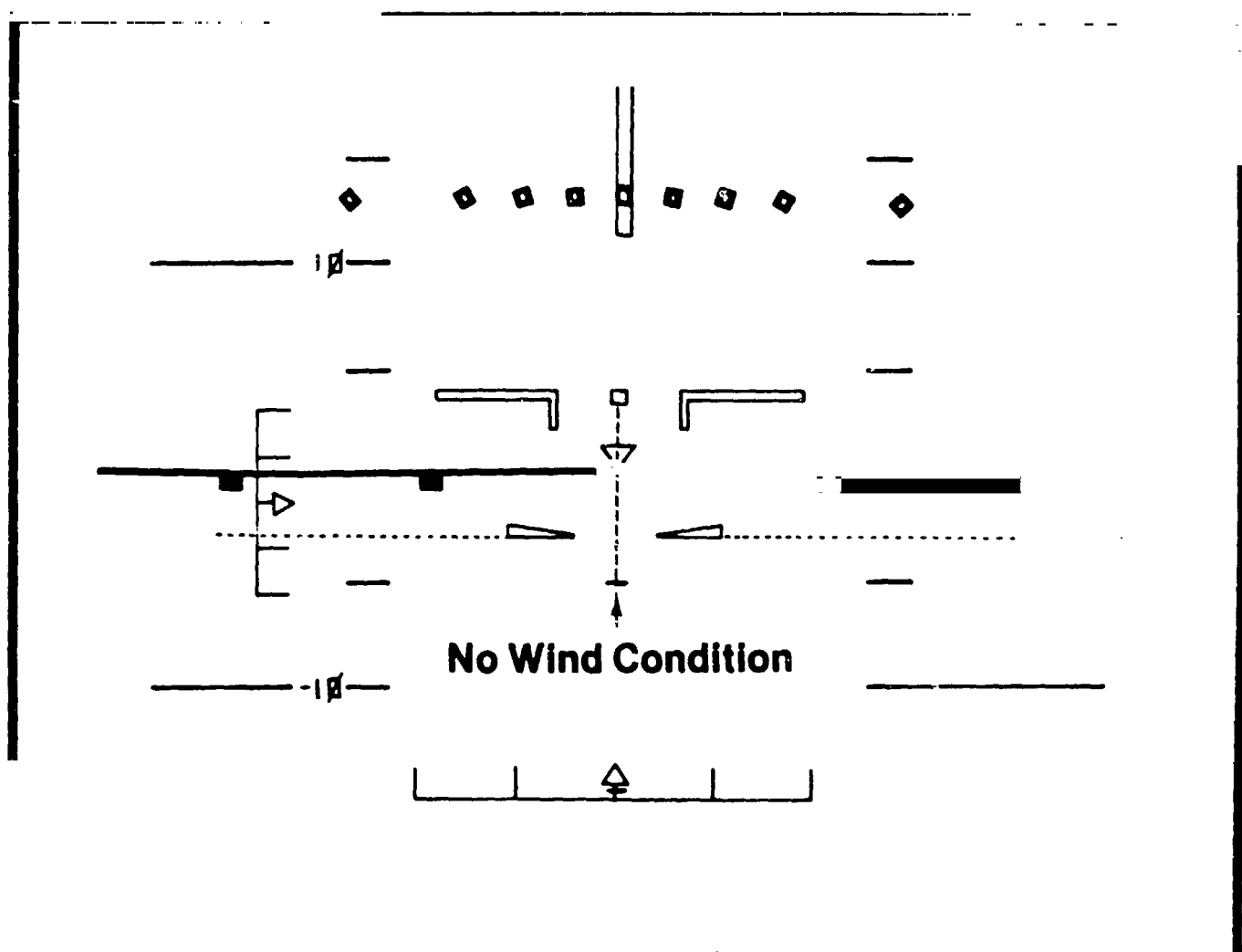


The track angle scale appears on the horizon line and uses **the runway center line as its zero reference**. The scale consists of plus and minus 10 degree and plus and minus 20 degree marks on either side of the extended runway centerline.

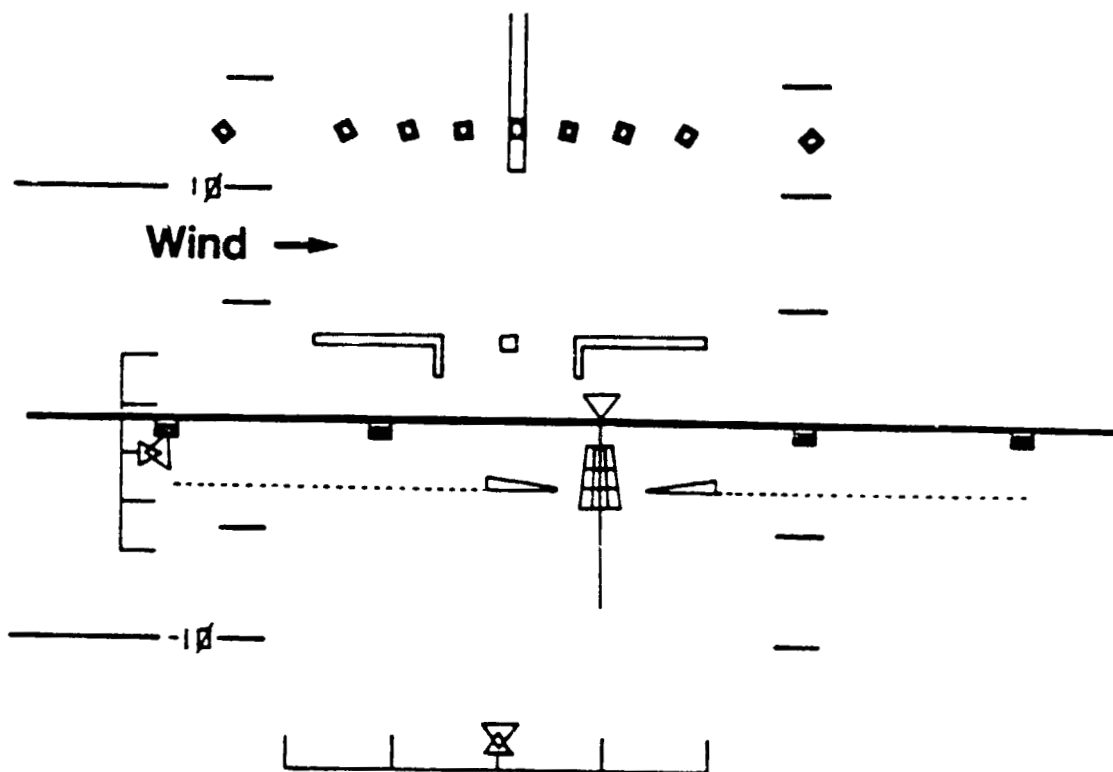


The track angle **SCALE** moves right and left on the horizon line, while the track angle pointer always remains vertically aligned with the flight path angle wedges.

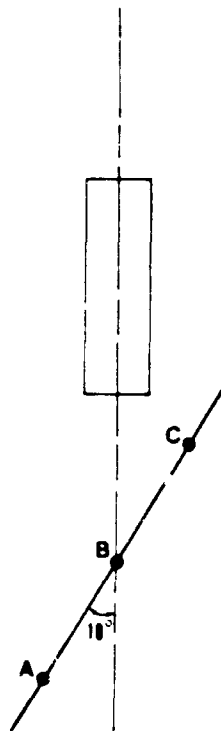
The track angle pointer and scale will always indicate the intercept angle of the aircraft's track with the extended runway centerline.



In a no wind condition, the airplane nose reference, will also be vertically aligned with the track angle pointer and the flight path angle wedges.

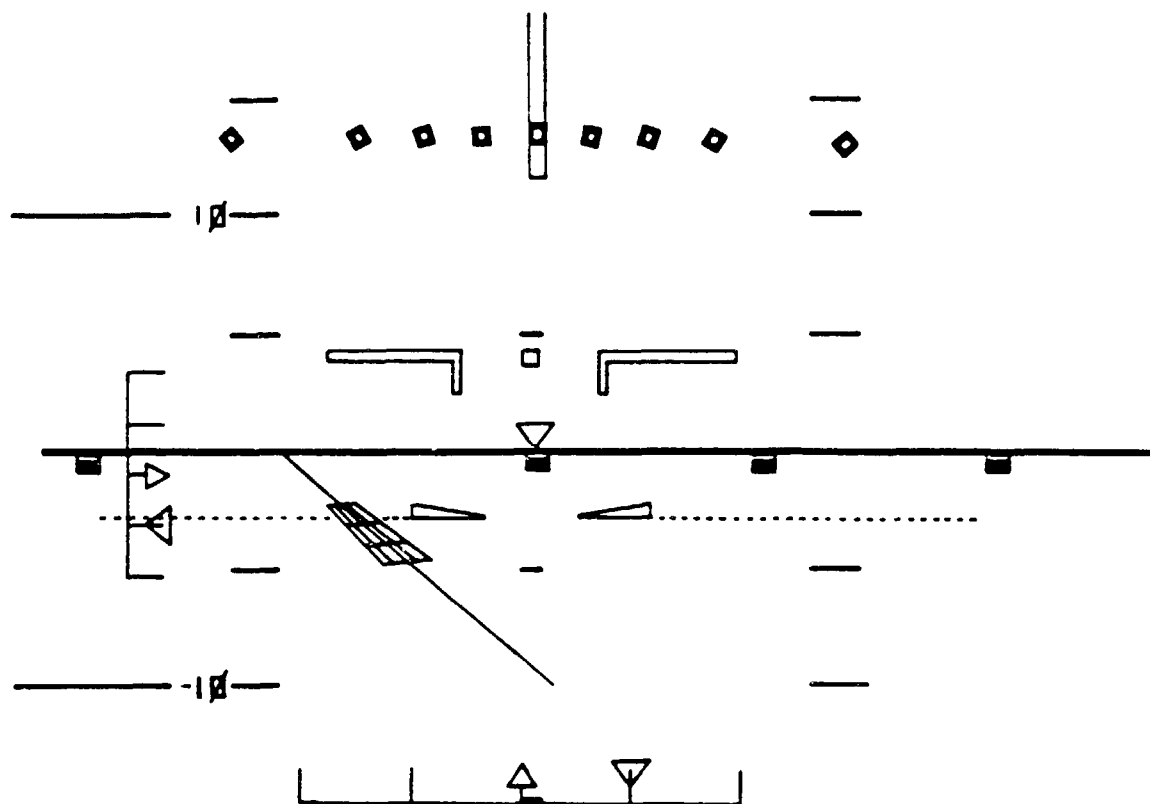


When a crosswind exists the nose reference will be on that side of the flight path angle wedges from which the wind is blowing.



To fully appreciate the value of the track angle scale and the track angle pointer let's look at a plan view of the localizer front course. We will label the three positions A, B, and C, which are on the same straight line intersecting the extended runway centerline at 10 degrees.

A no-wind condition exists. The aircraft is flying from A to B. Its track is the line A-B and the intercept angle is 10 degrees.

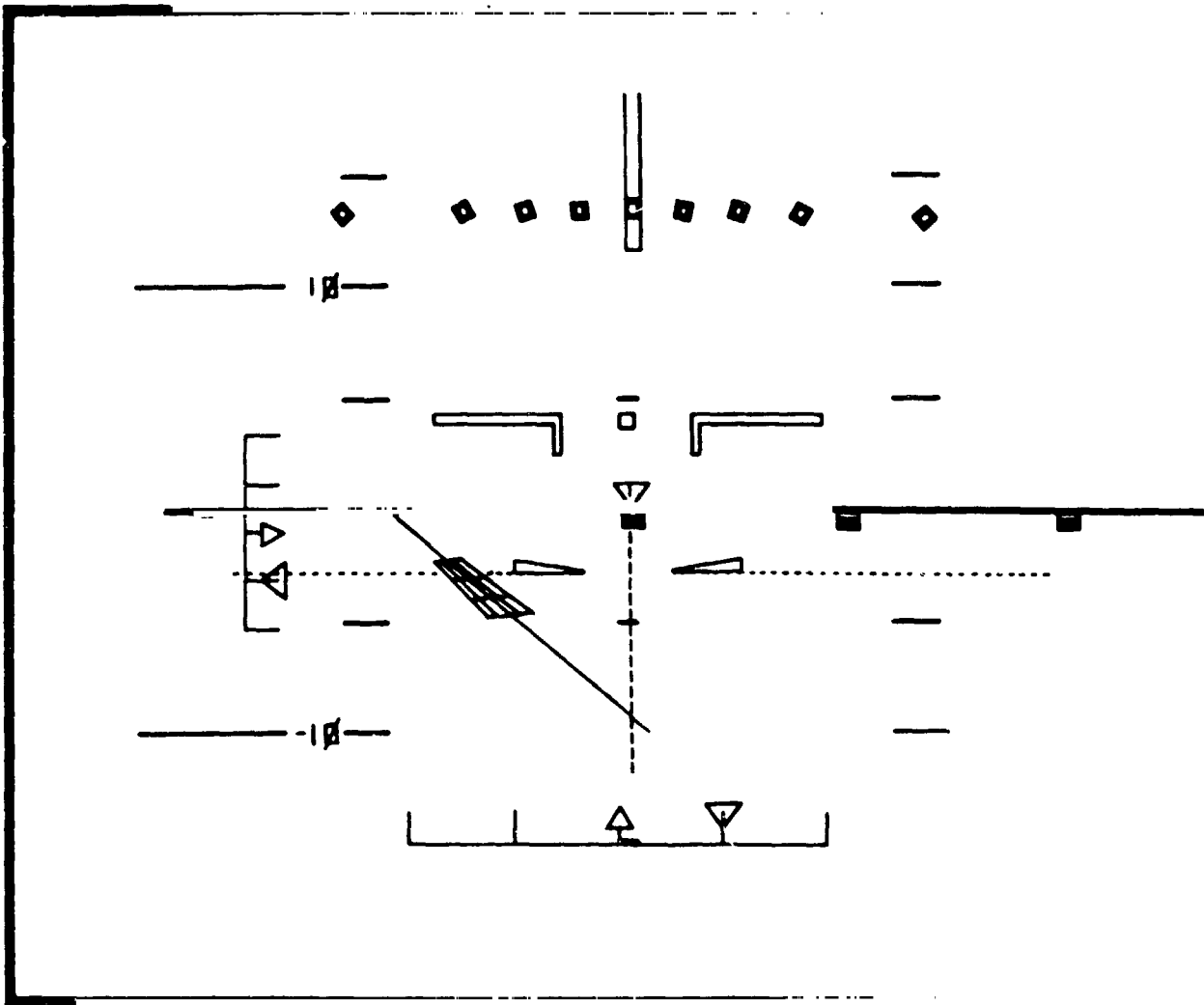


The EADI display for the aircraft at position A will look like this.

First we see that the aircraft nose reference and the track angle pointer are vertically aligned, as there is no crosswind.

Next, the track angle scale has moved to the left leaving the track angle pointer showing a 10° right intercept to the localizer. The localizer is to the right as it should be.

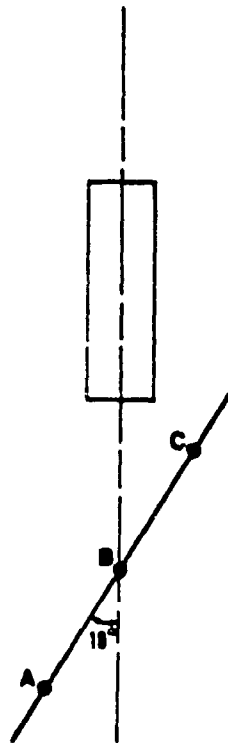
Can you tell from this display where you will intercept the localizer? Will it be far out, close in or no interception at all?



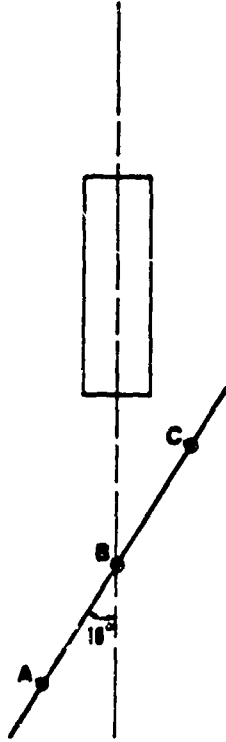
The answer uses a little geometry. Drop a plumb line from the track angle pointer. It will always pass between the flight path angle wedges.

Where it intersects the extended runway centerline is an **Indication** of where you will cross the center of the localizer.

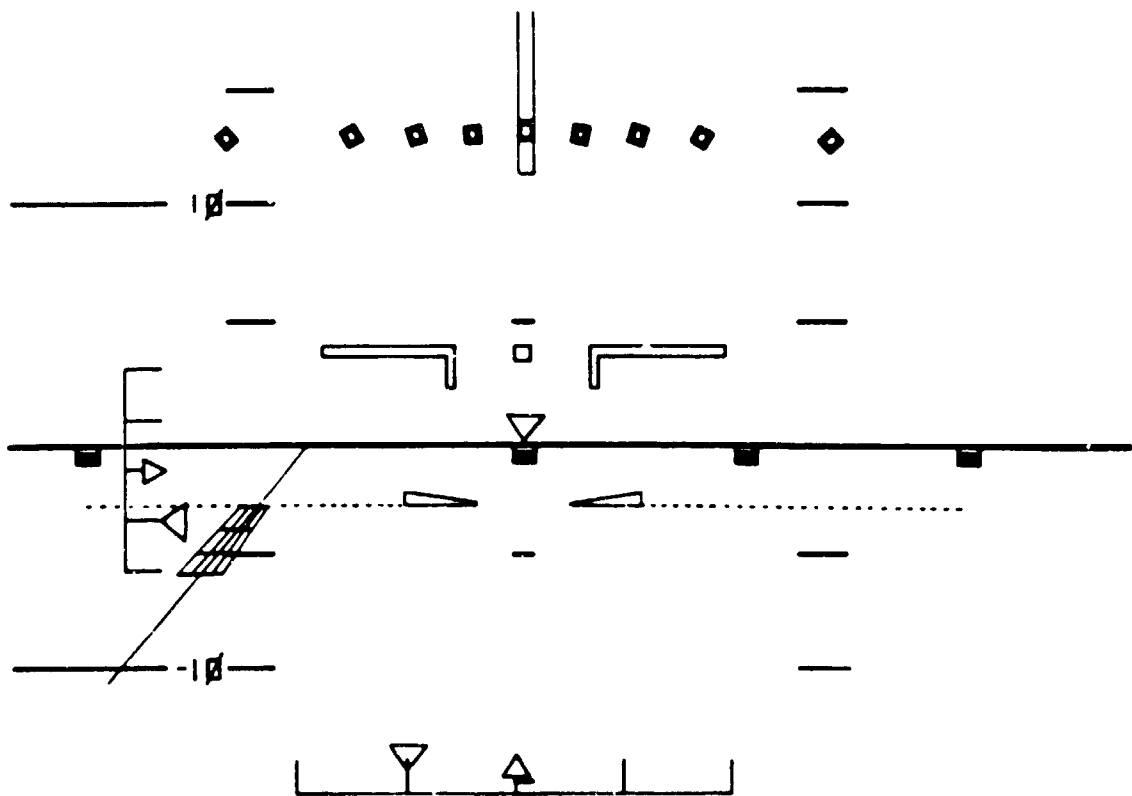
In this case you can intercept the localizer far enough out to make a smooth left turn on to the localizer. If you don't turn in, but continued on the original track.....



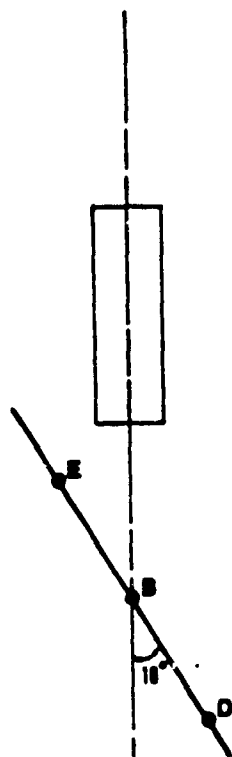
you would cross the runway at position B and the EADI display will look like this.



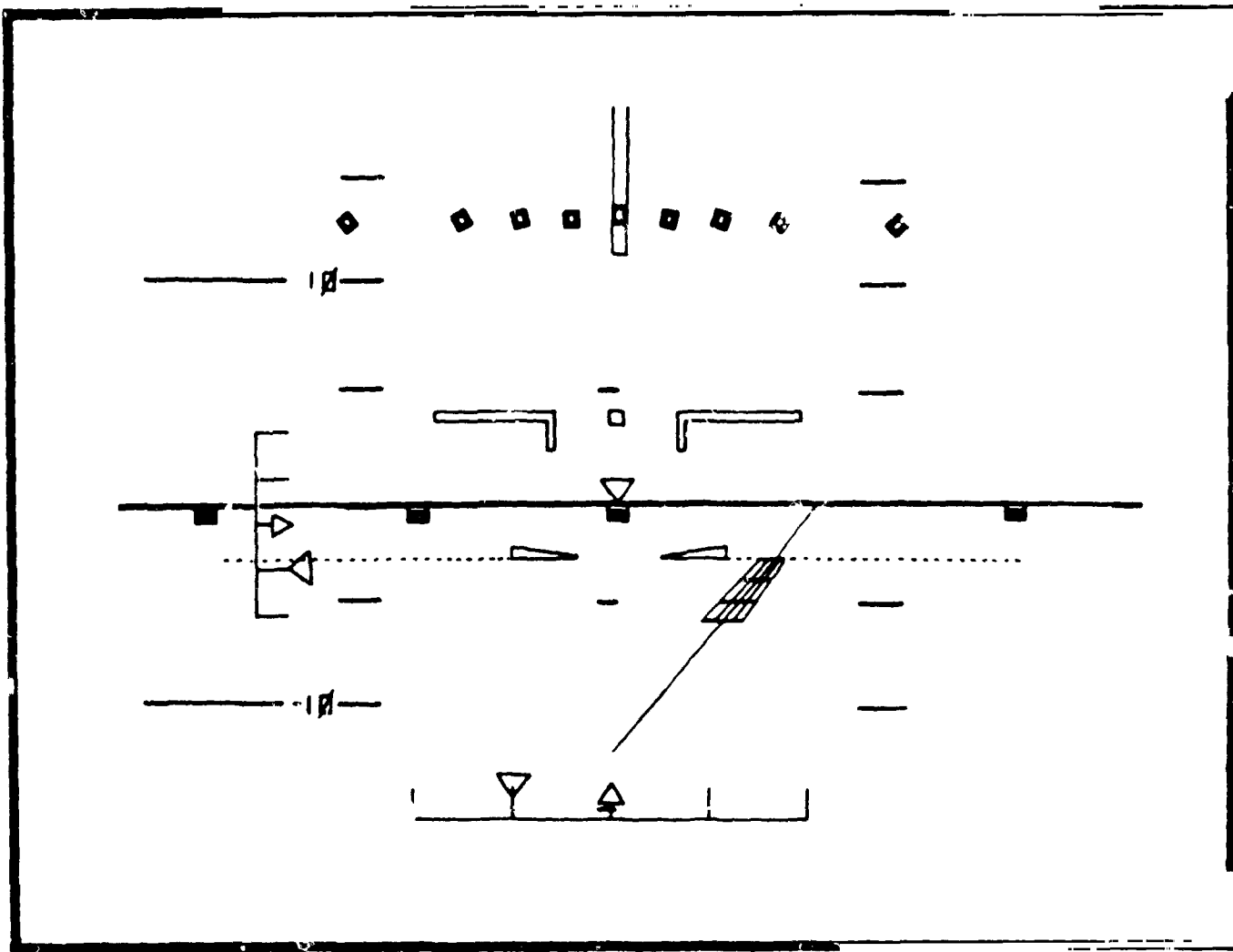
However, let's again continue on the original track and see what the EADI display shows at position C,...



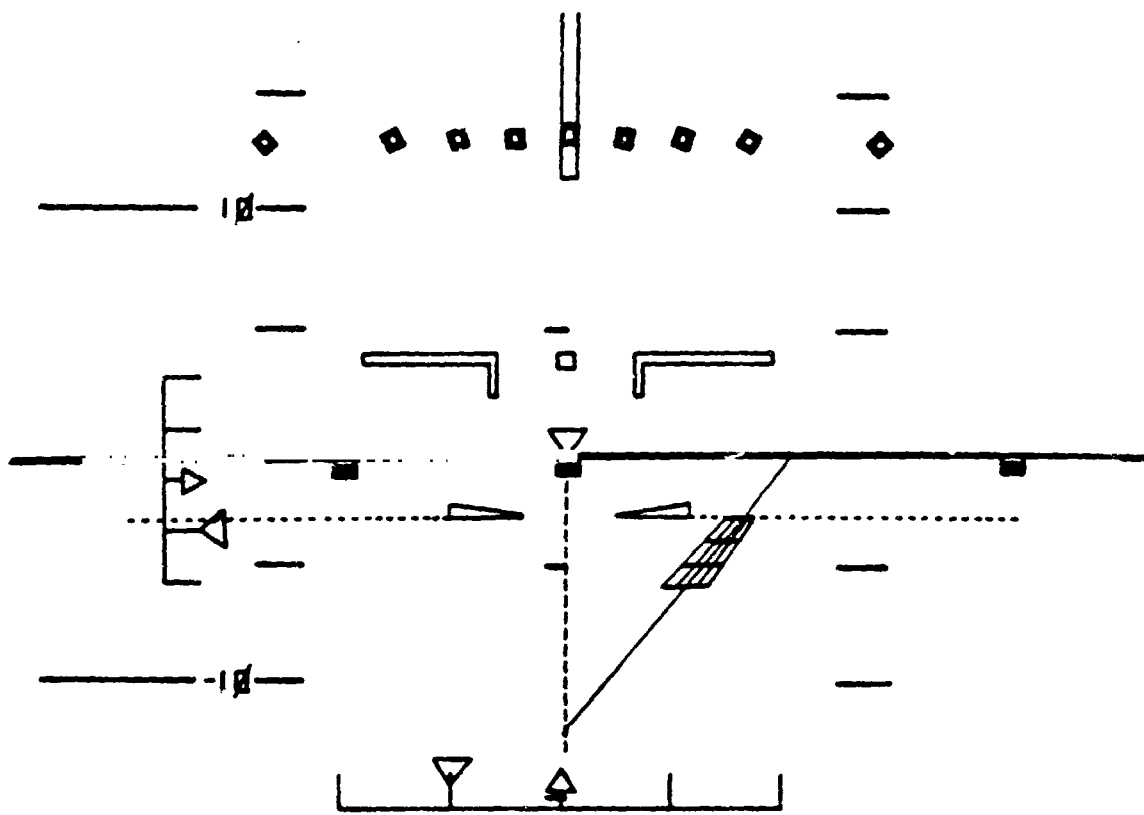
Very close in and to the right of the localizer!



Now, let's see what the EADI display looks like when on a track from position D to B to E. At position D...

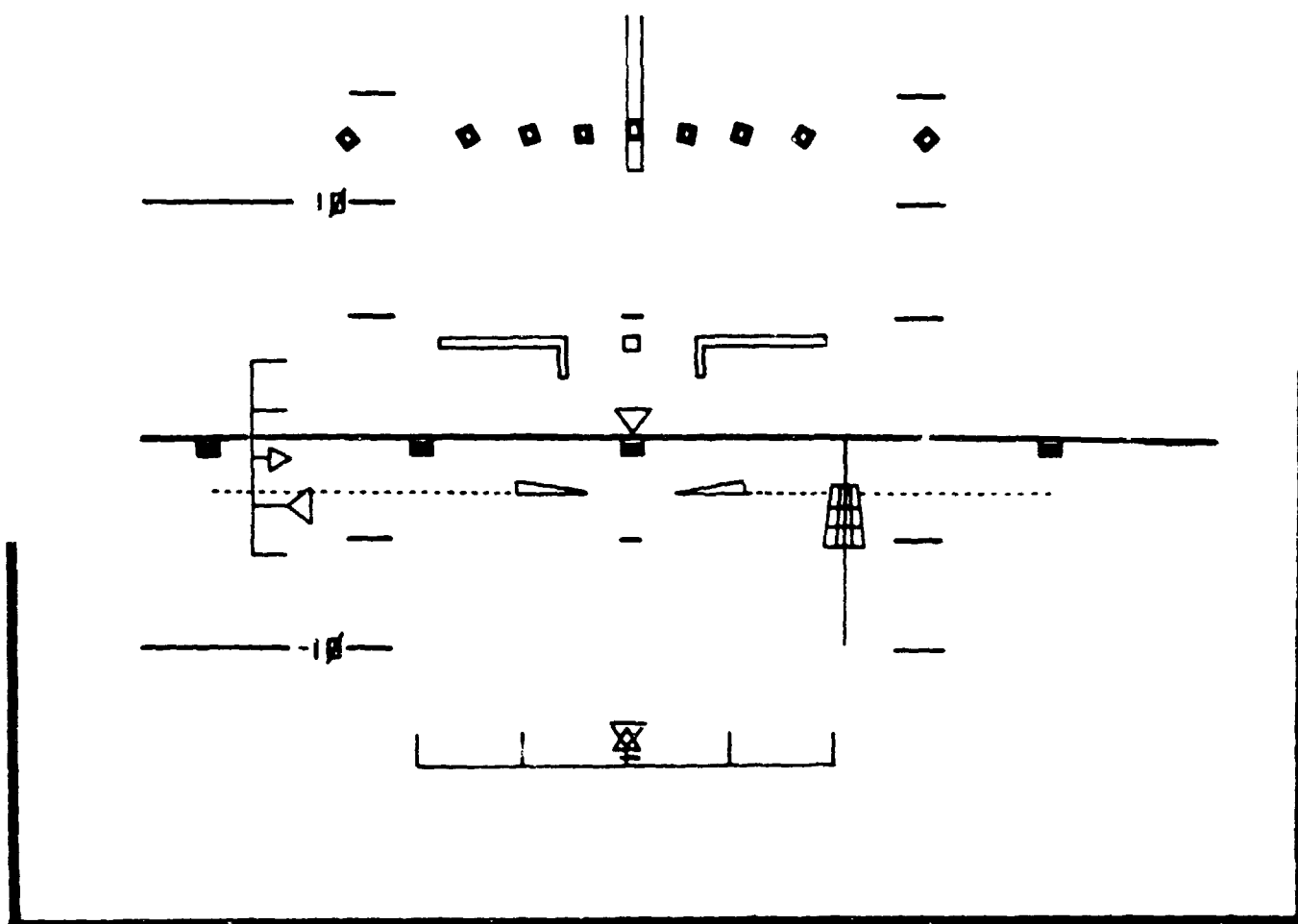


the track angle pointer shows no drift correction, and the aircraft is on a minus 10 degree or 10 degree left intercept to the localizer course. Once again where will you intercept the localizer? The answer is simple enough,...

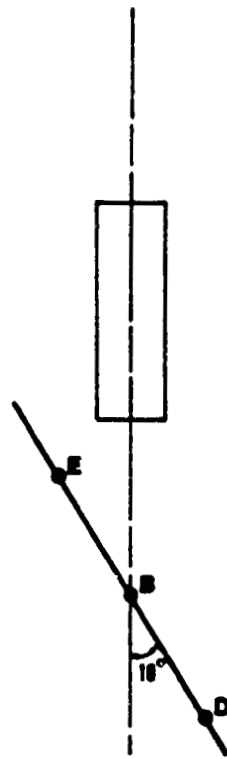


just visualize a plumb line down from the track angle pointer to the extended runway centerline.

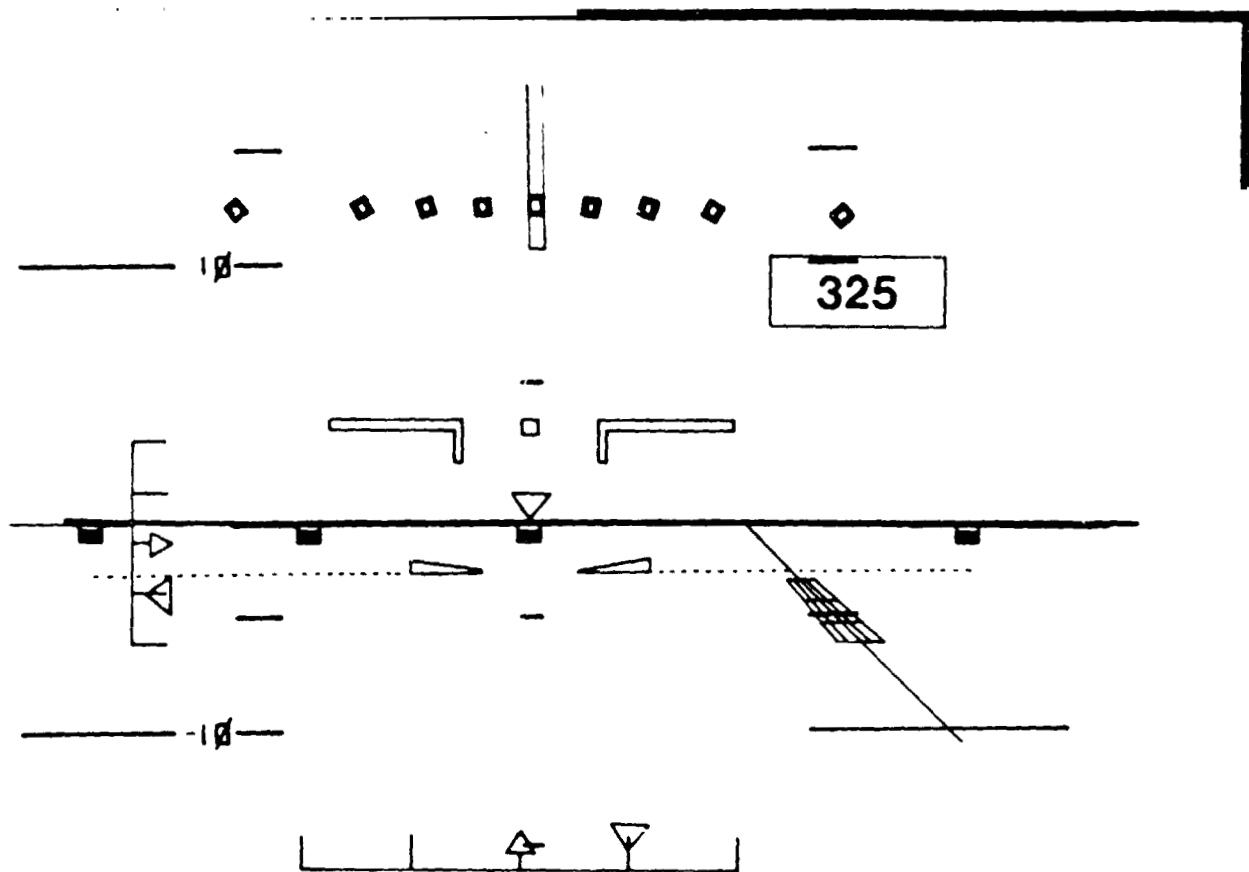
The intersection indicates that you will intercept the localizer...



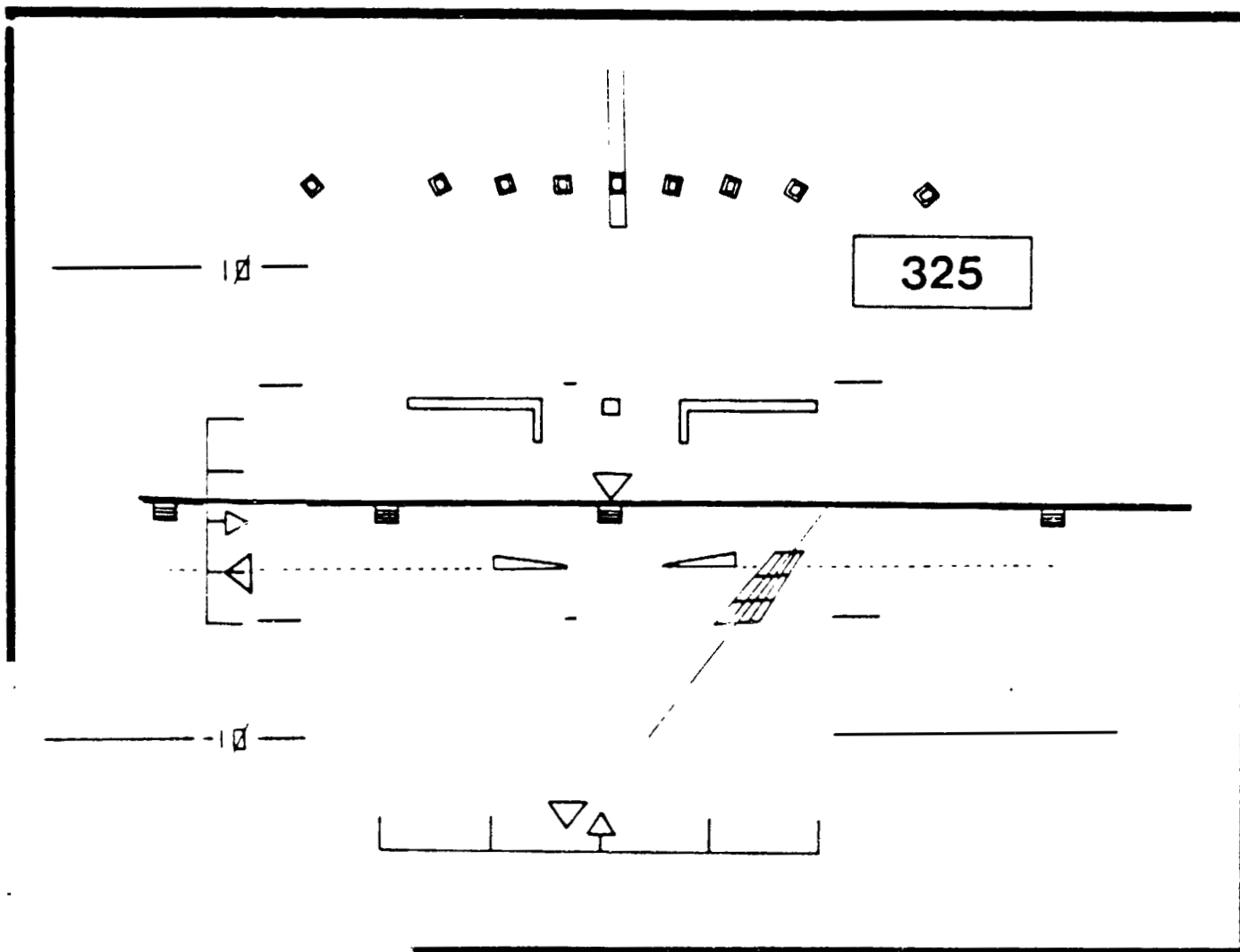
...At point B; the EADI display then looks like this: Note that whenever the aircraft is on localizer centerline, the perspective runway is always perpendicular to the track angle scale and the horizon.



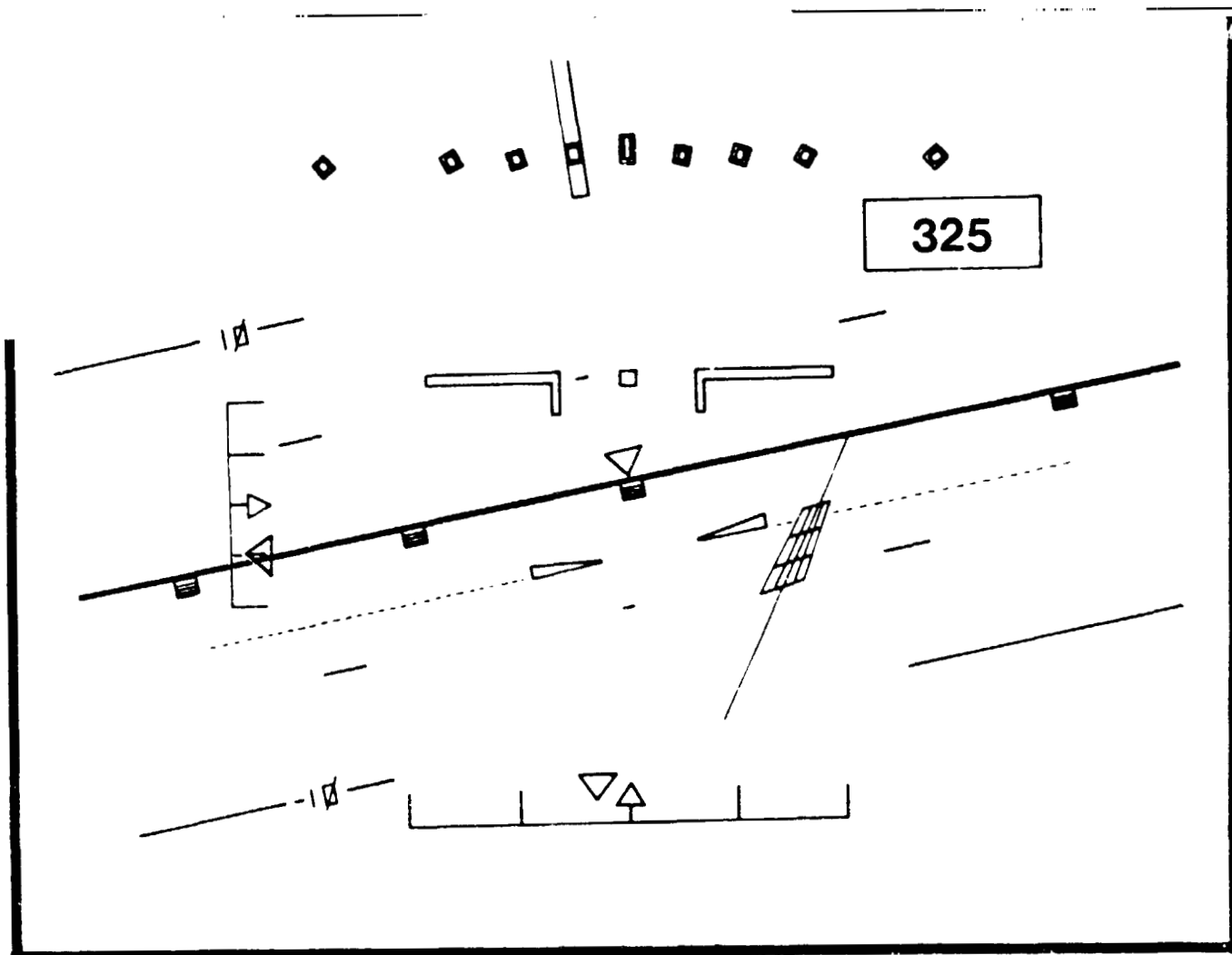
If you shoot through to position E,...



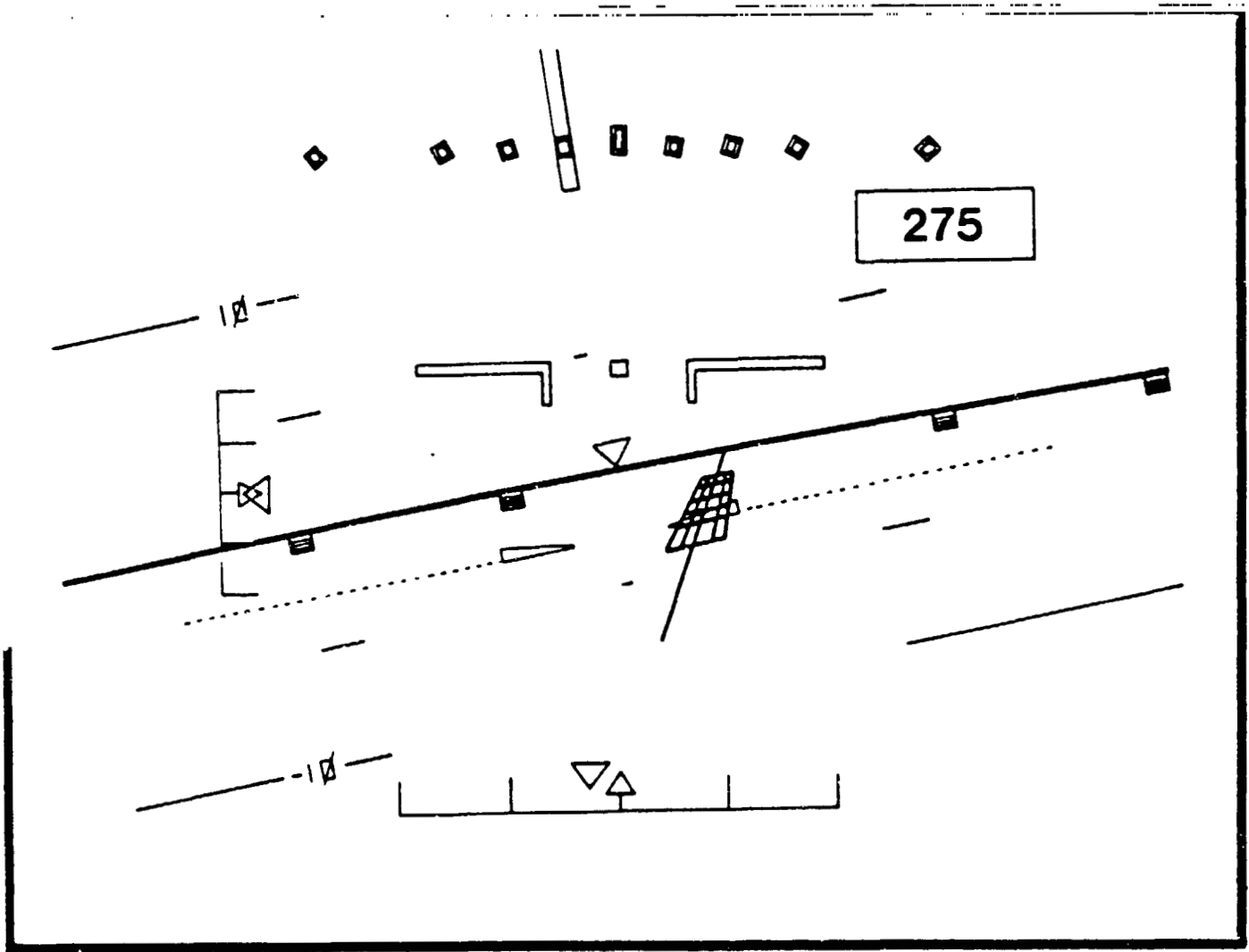
the EADI display shows you very close in, the localizer to your right, and then a very steep turn would be required to re-intercept.



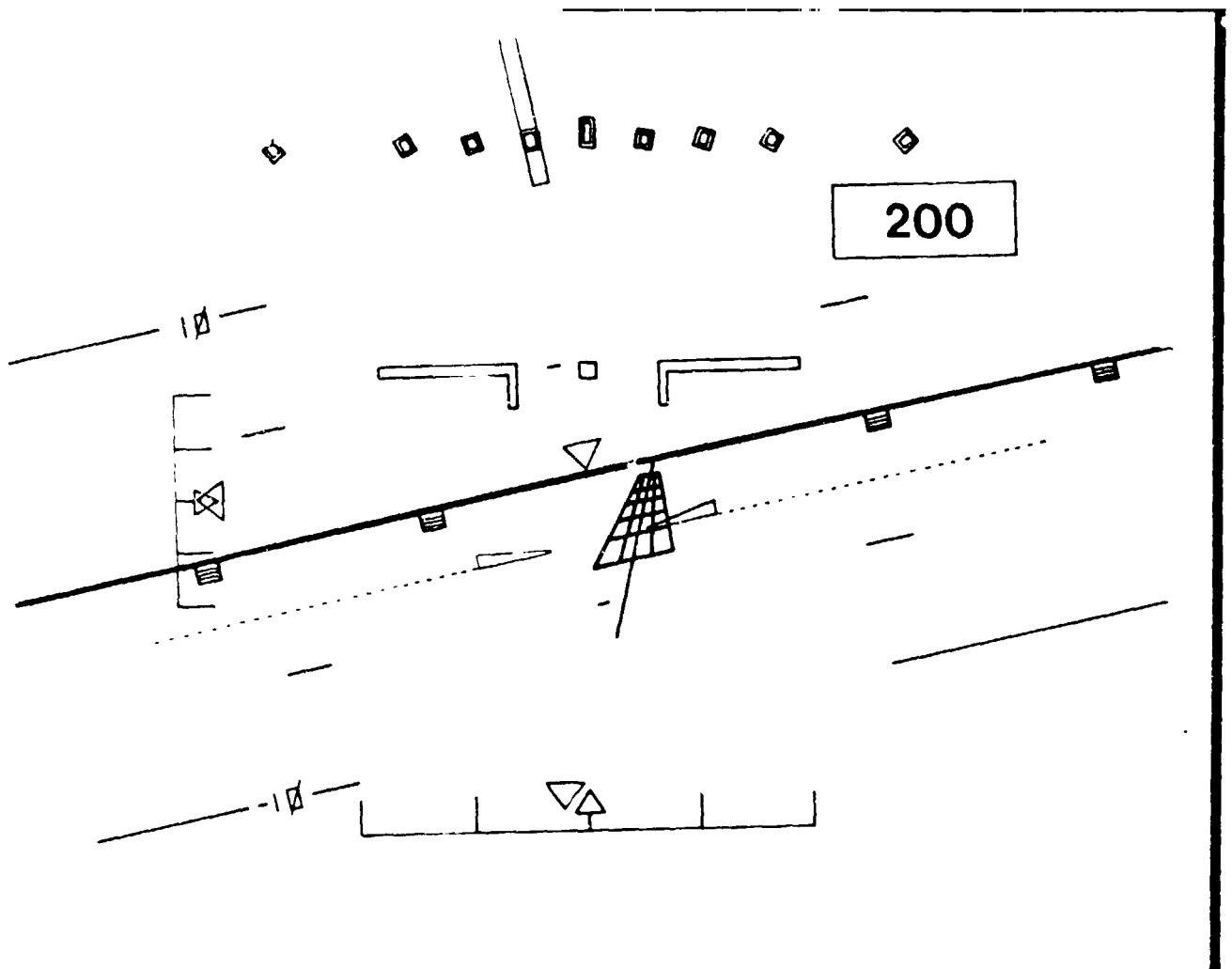
Now, let's back up to just before intercepting the localizer and see how the track angle scale moves as you turn in to track the localizer.



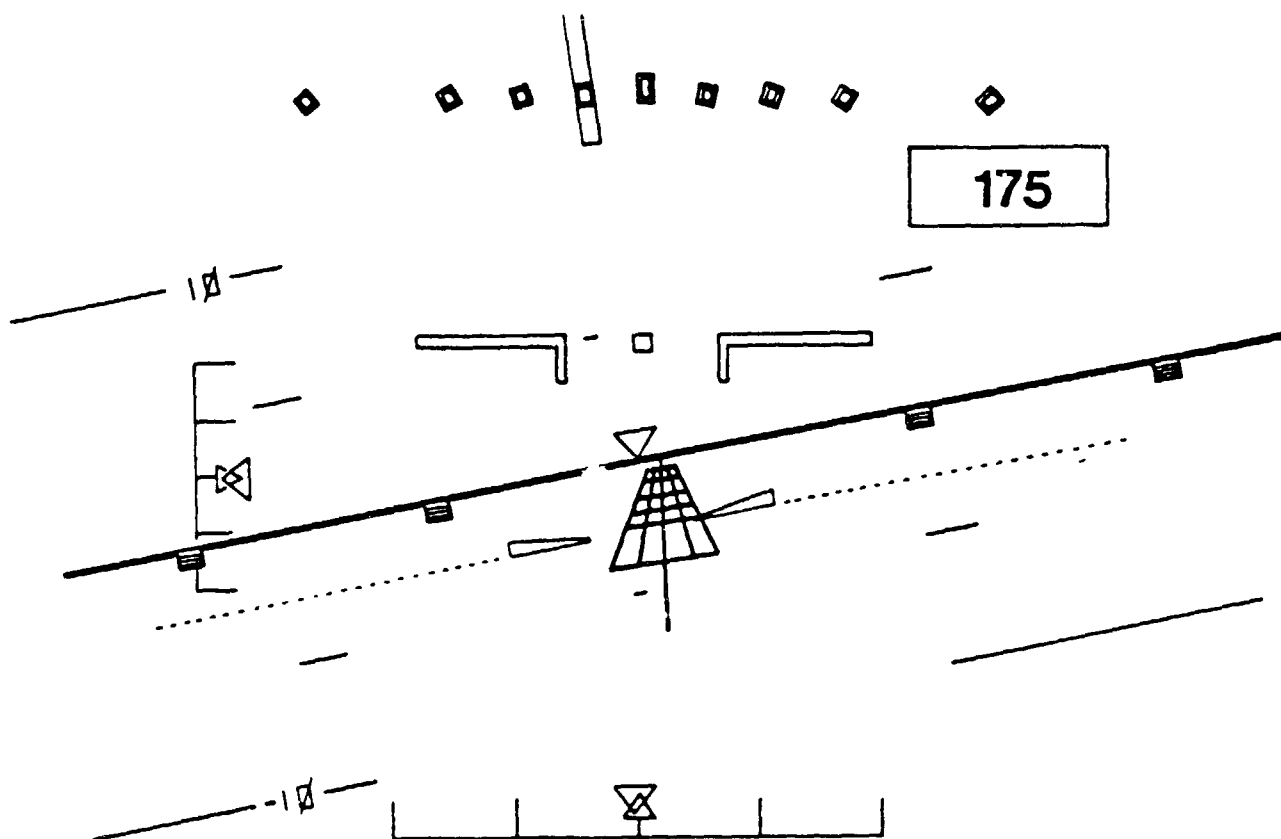
Start a right turn,



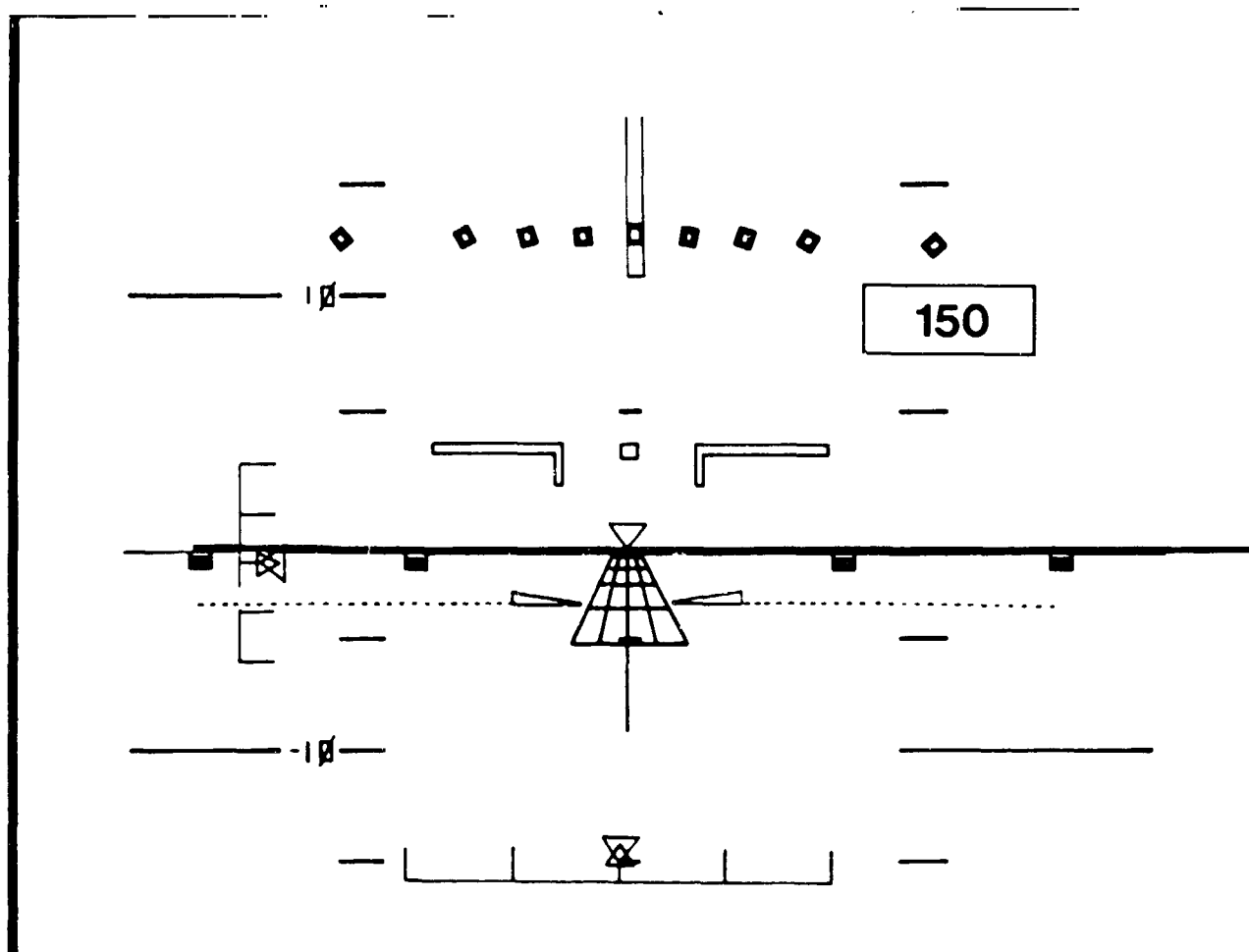
halfway through the turn note the position of the track angle scale; it and the runway are moving to the left. The track angle pointer is now showing an intercept of 5° .



Here's what it looks like at two-thirds of the way through the turn,...



and here's where you would begin the roll out.



When you roll out on the localizer, both localizer and glide slope pointers are centered.

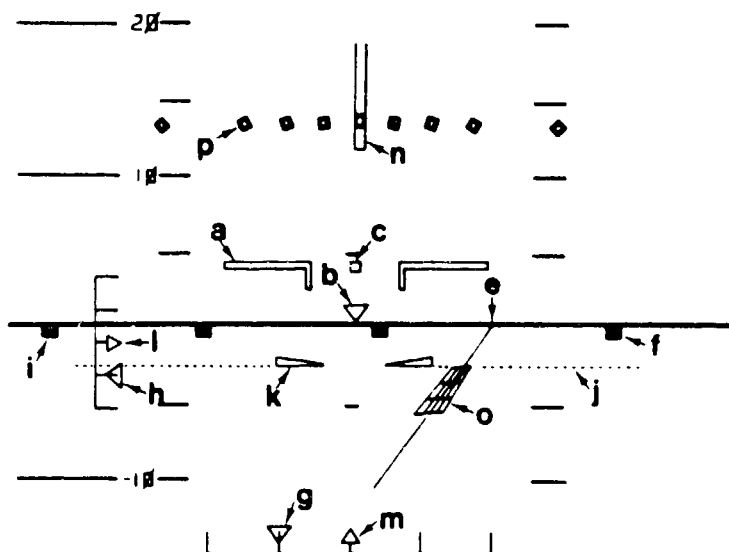
You can now see why the flight path wedges are separated...so you can see the perspective runway and extended centerline.

Look carefully at the touch down zone. When the dashed, pitch reference line is set to the glideslope angle for this airport's glideslope --- here it's minus 3 degrees --- and the glideslope pointer is centered, then the touchdown zone is the first horizontal runway line beyond the threshold. The pitch reference line and the flight path angle wedges are all horizontally aligned with the touchdown zone.

QUIZ

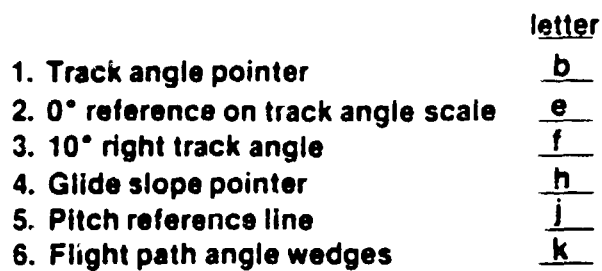
Now, it's time for another quick quiz. Here's the first question...restart the tape after you've chosen your answer.

1. 2. 3.

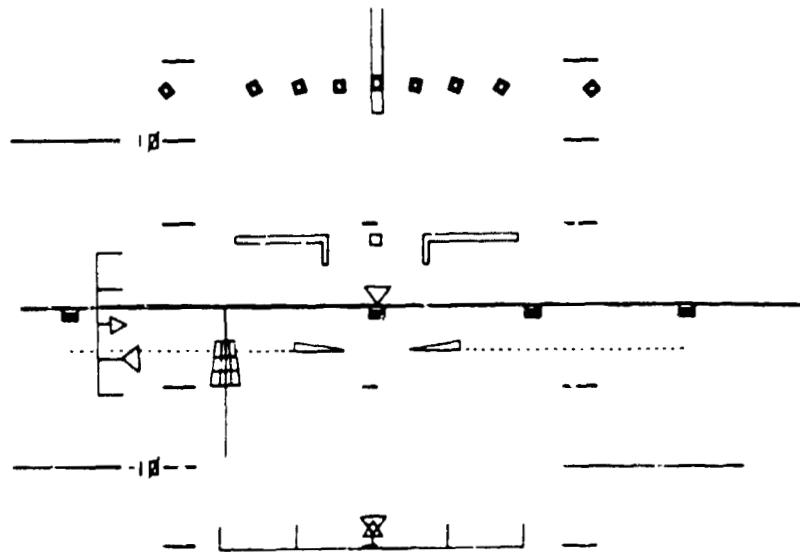


- | | letter |
|--------------------------------------|---------------|
| 1. Track angle pointer | _____ |
| 2. 0° reference on track angle scale | _____ |
| 3. 10° right track angle | _____ |
| 4. Glide slope pointer | _____ |
| 5. Pitch reference line | _____ |
| 6. Flight path angle wedges | _____ |

From the display shown, identify the following symbols and their interpretation. Write your answers on your answer sheet.



67

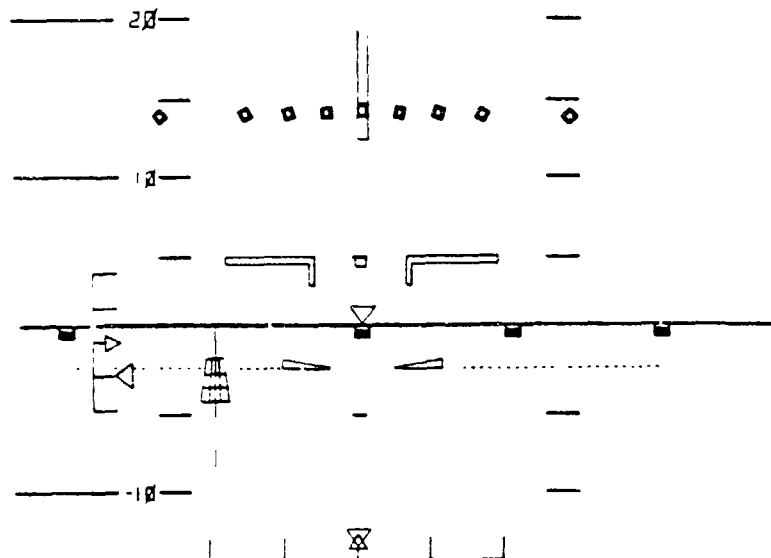


As Shown

- | | | | |
|------------------------|------|----------|-------|
| 1. Localizer Pointer | left | centered | right |
| 2. Glide Slope Pointer | high | centered | low |
| 3. Flight Path Angle | 0° | -3° | -5° |

-continue to next slide-

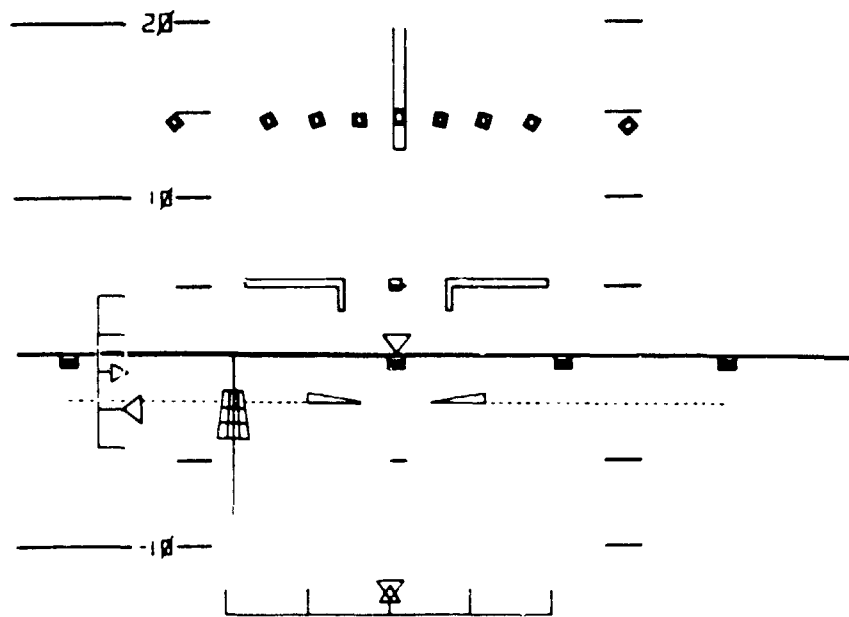
Your interpretation of the display should associate with each symbol information for the control of the aircraft. For the nine symbols listed, choose among the available answers the one you know to be correct. Restart the tape after you've chosen the first three.



Symbol	As Shown		
4. Pitch Reference Line	0°	.3°	.5°
5. Track Angle Pointer	left	zero	right
6. Runway centerline location with respect to aircraft	left	zero	right

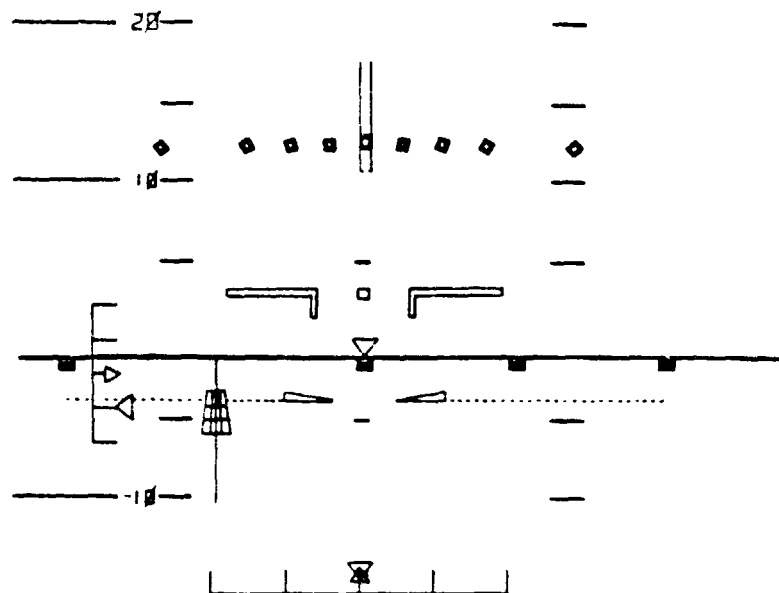
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Here's the next three of the nine part question. Restart the tape when you've chosen your answer to parts four through six.



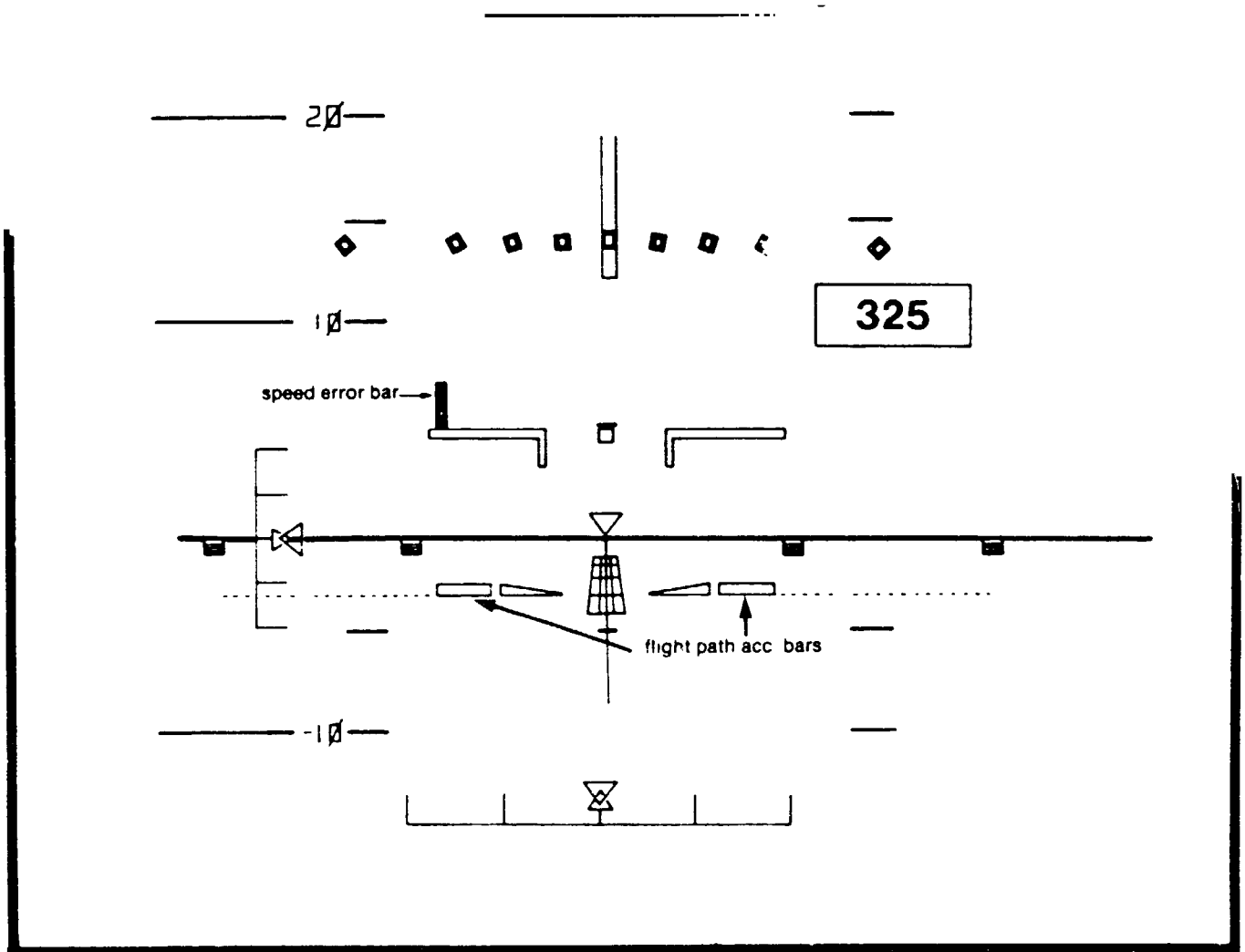
Symbol	As Shown		
7. Touchdown aim point	long	TDZ	short
8. Bank Angle	left	zero	right
9. Drift Correction	left	zero	right

And here's the final three parts. After you've chosen your answers, re-start the tape.

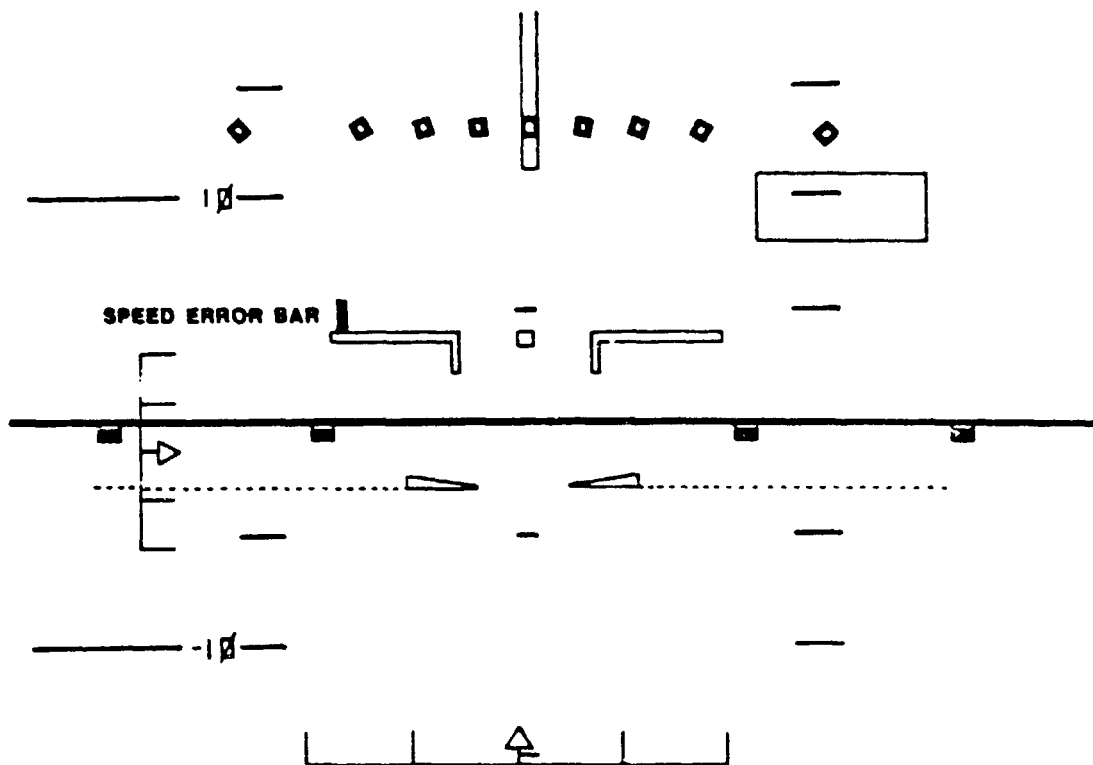


- | | | |
|-------------|----------|---------|
| 1. Centered | 4. -3° | 7. Long |
| 2. Low | 5. Right | 8. Zero |
| 3. -3° | 6. Zero | 9. Zero |

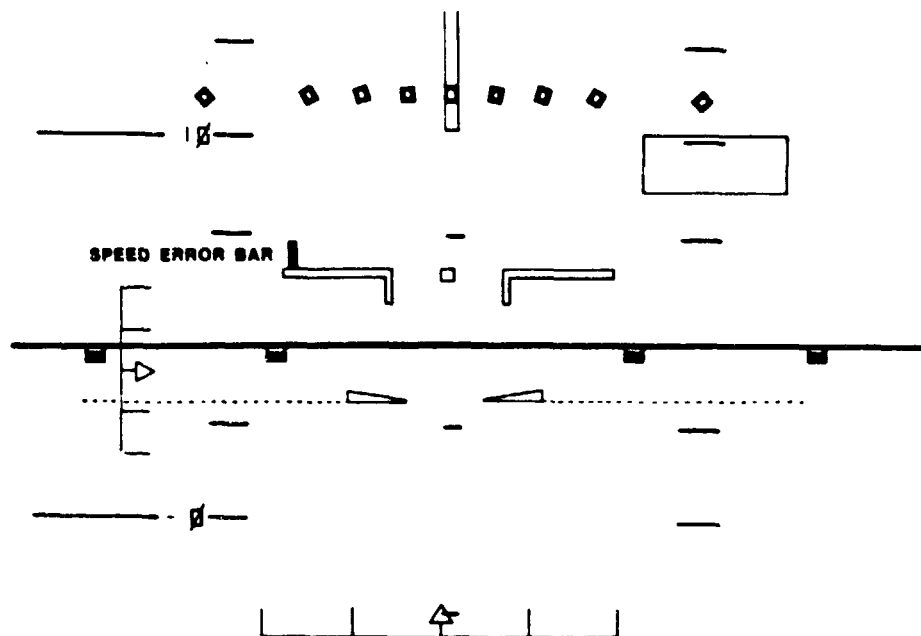
After you've checked your answers, restart the tape and we'll proceed with the next section of your familiarization and interpretation of the EADI and its symbols.



There are 2 remaining symbols on the EADI. They are the speed error bar and flight path acceleration bars.



The length of the speed error bar represents the difference between actual airspeed and commanded airspeed.



"Speed error bar will appear when:
1. a new speed is commanded
or
2. a change in drag occurs."

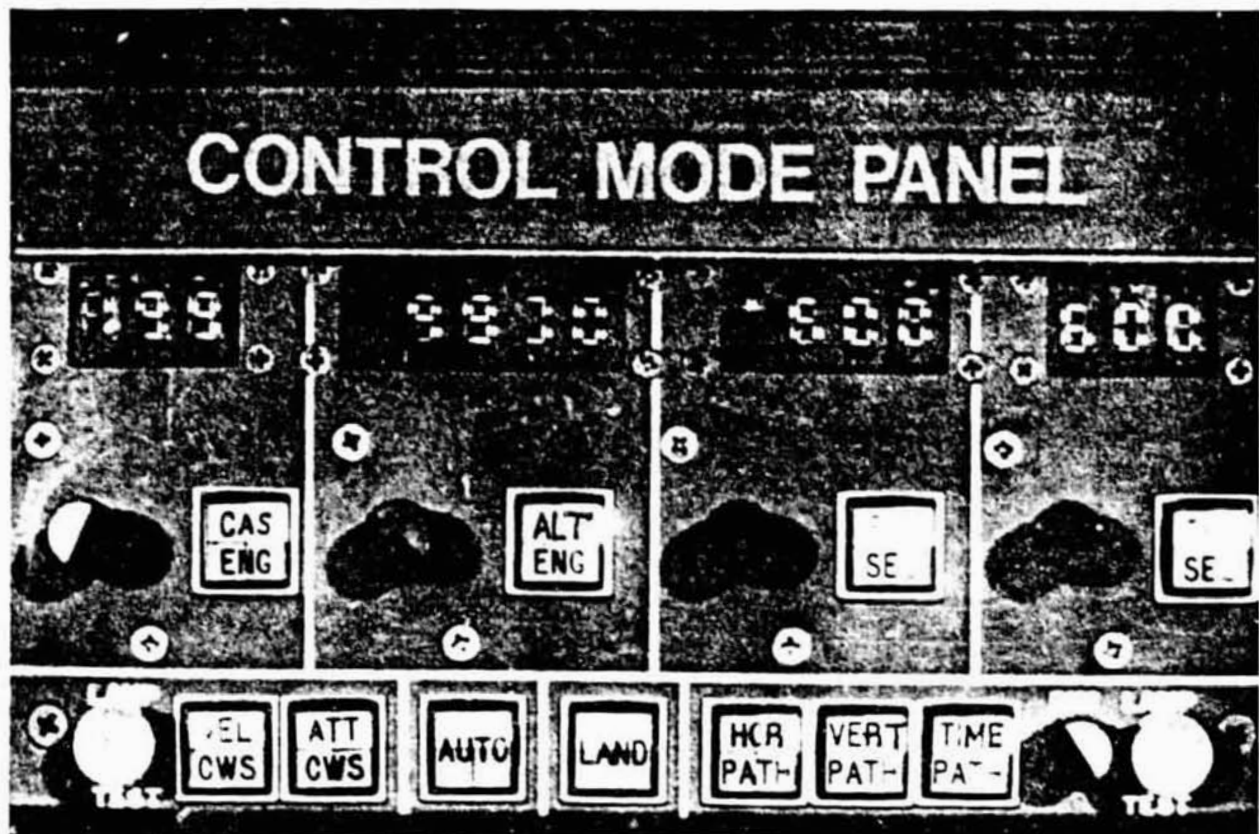
The speed error bar will appear whenever a new speed is commanded to the system or there is a change in drag.

“In Automatic Thrust Control mode the pilot sets speed and flight path angles.

- Then -

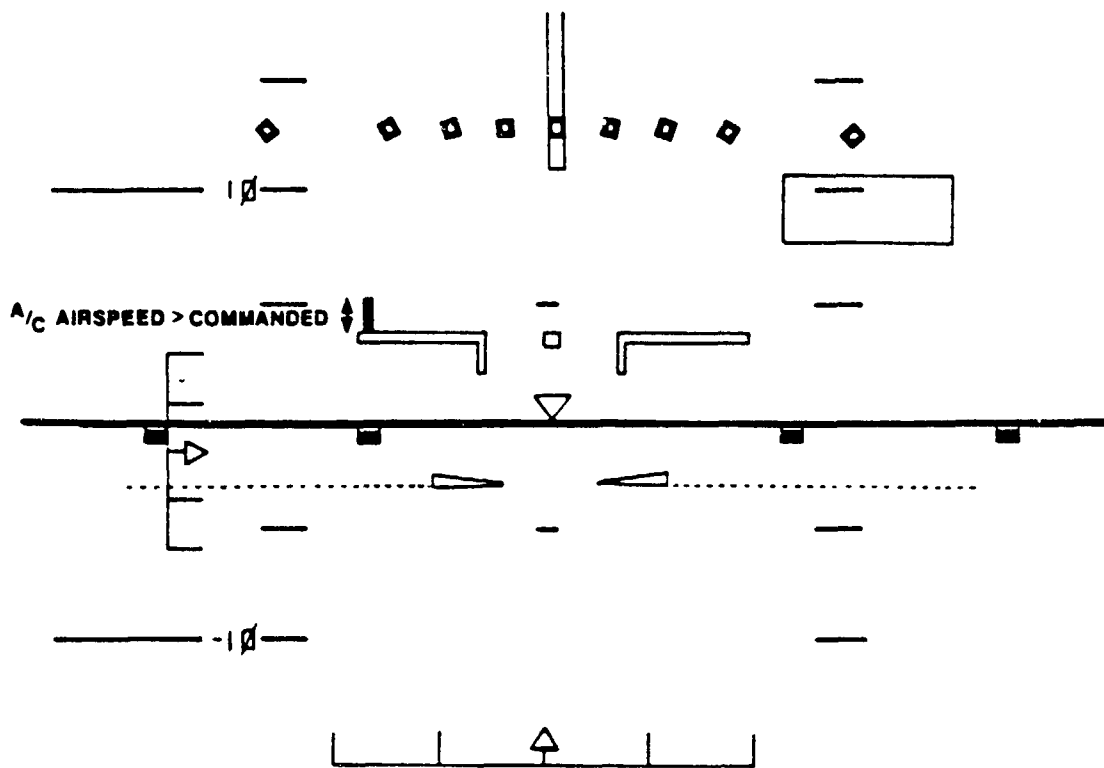
The flight control system automatically adjusts the throttles.

Power control will be accomplished in the automatic thrust control mode. The pilot sets his desired speeds and flight path angles. The Flight Control System adjusts the throttles.

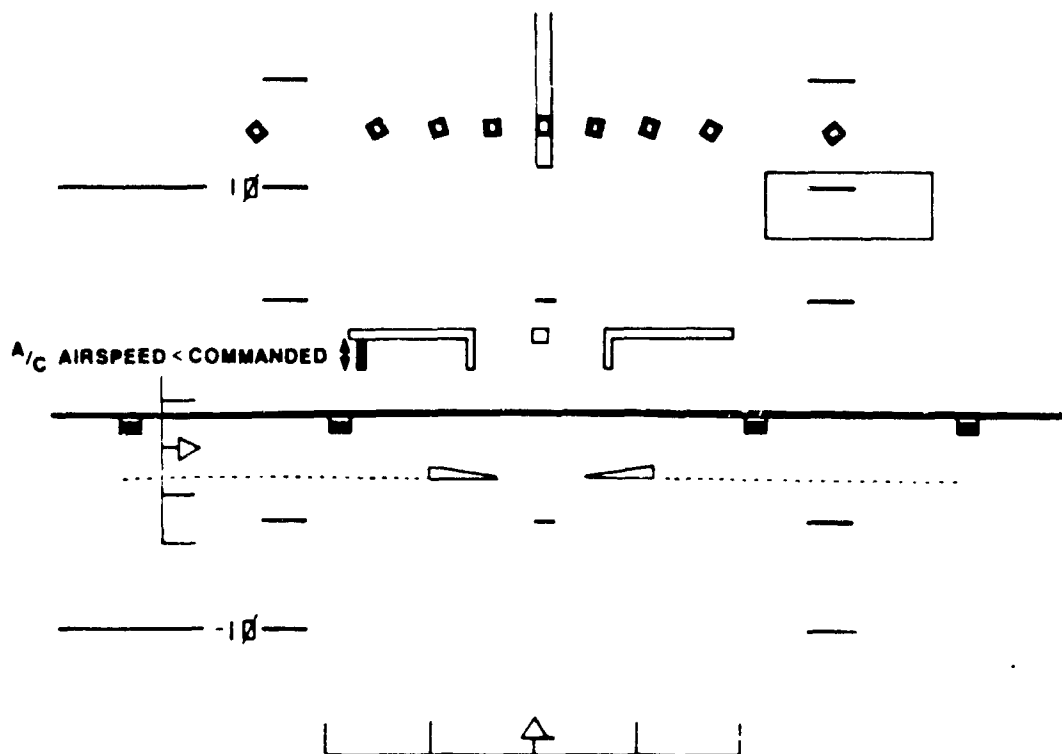


On the Advanced Guidance and Control System — or AGCS Control Mode Panel, is the Commanded Airspeed Knob and digital display.

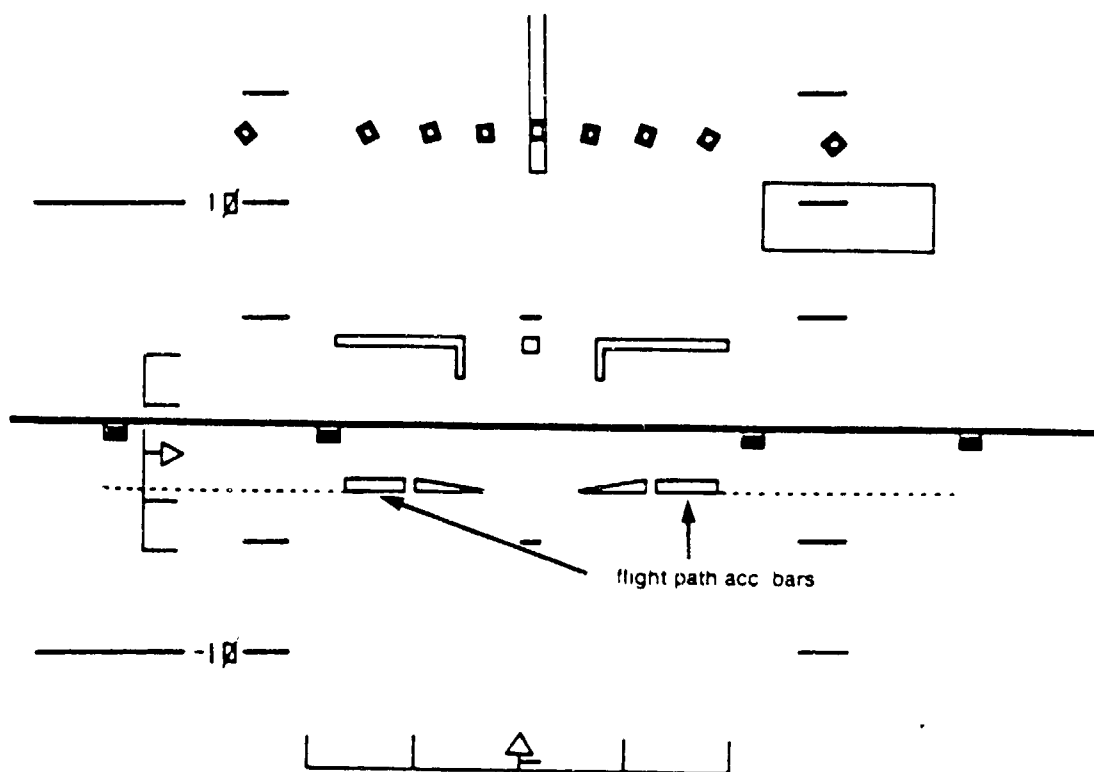
The knob and display above it is on the far left side of the panel next to and slightly above the calibrated airspeed engage button.



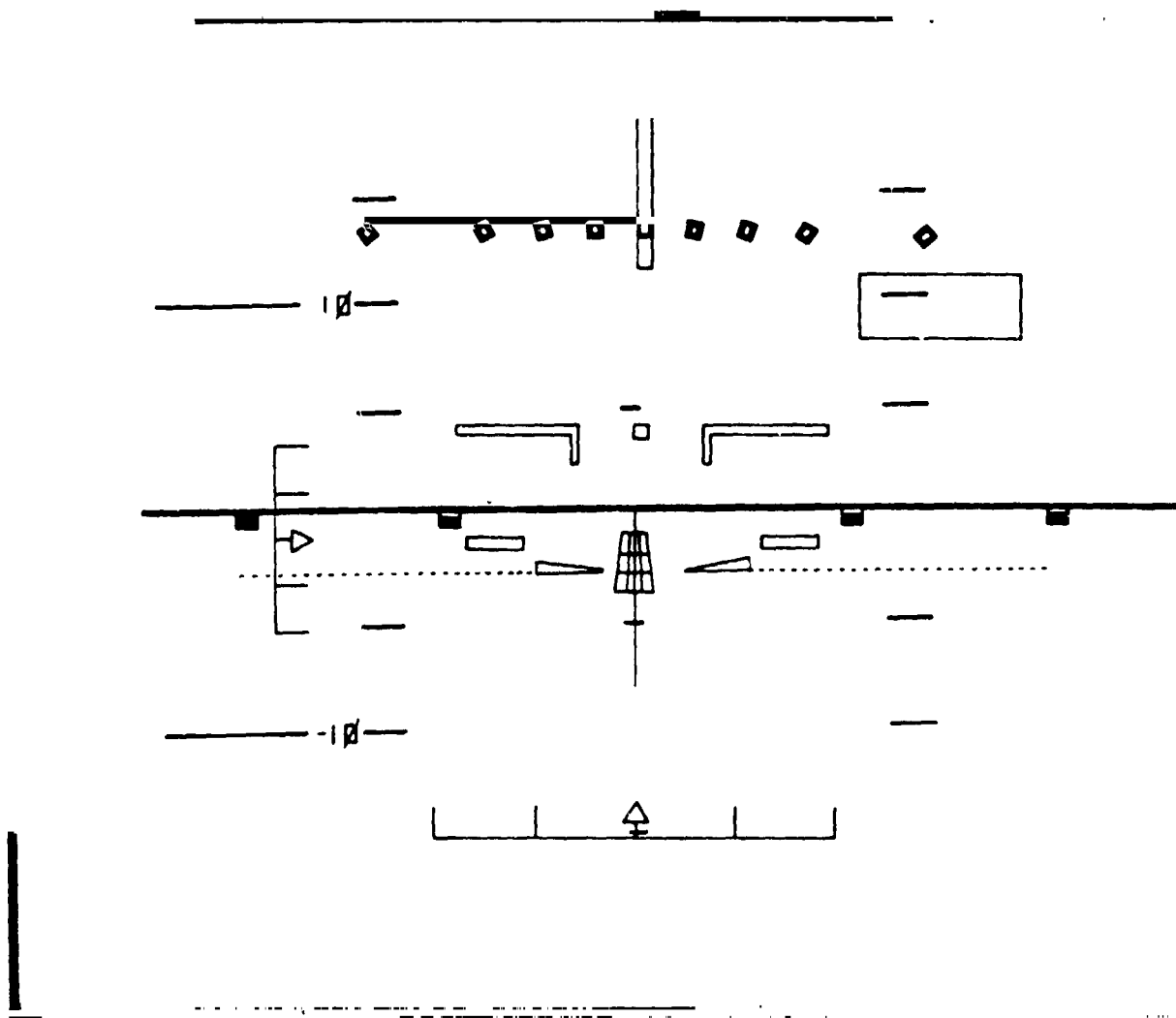
If actual airspeed is greater than that set in the window, the speed error bar will extend above the wing. Power is then automatically reduced to slow the airplane to the commanded speed.



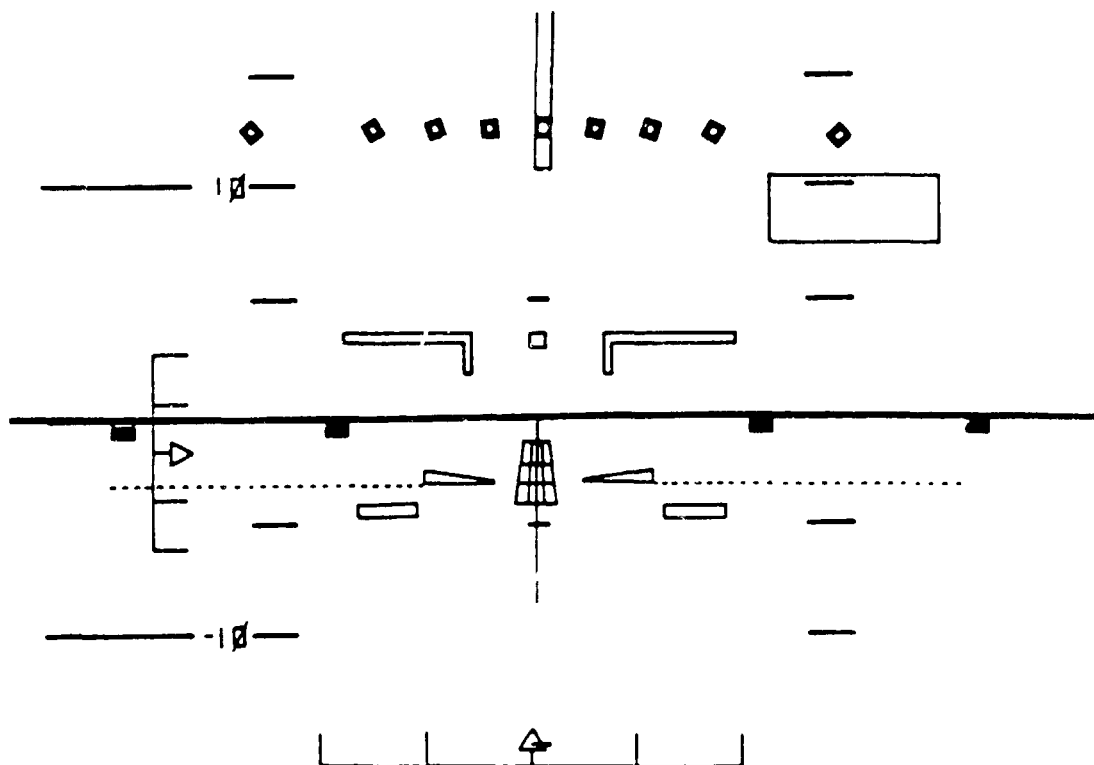
If actual airspeed is less than that set in the window, the speed error bar will extend down below the wing and the power will be automatically increased. When actual speed and desired speed are the same, the speed error bar will disappear and the power will remain constant.



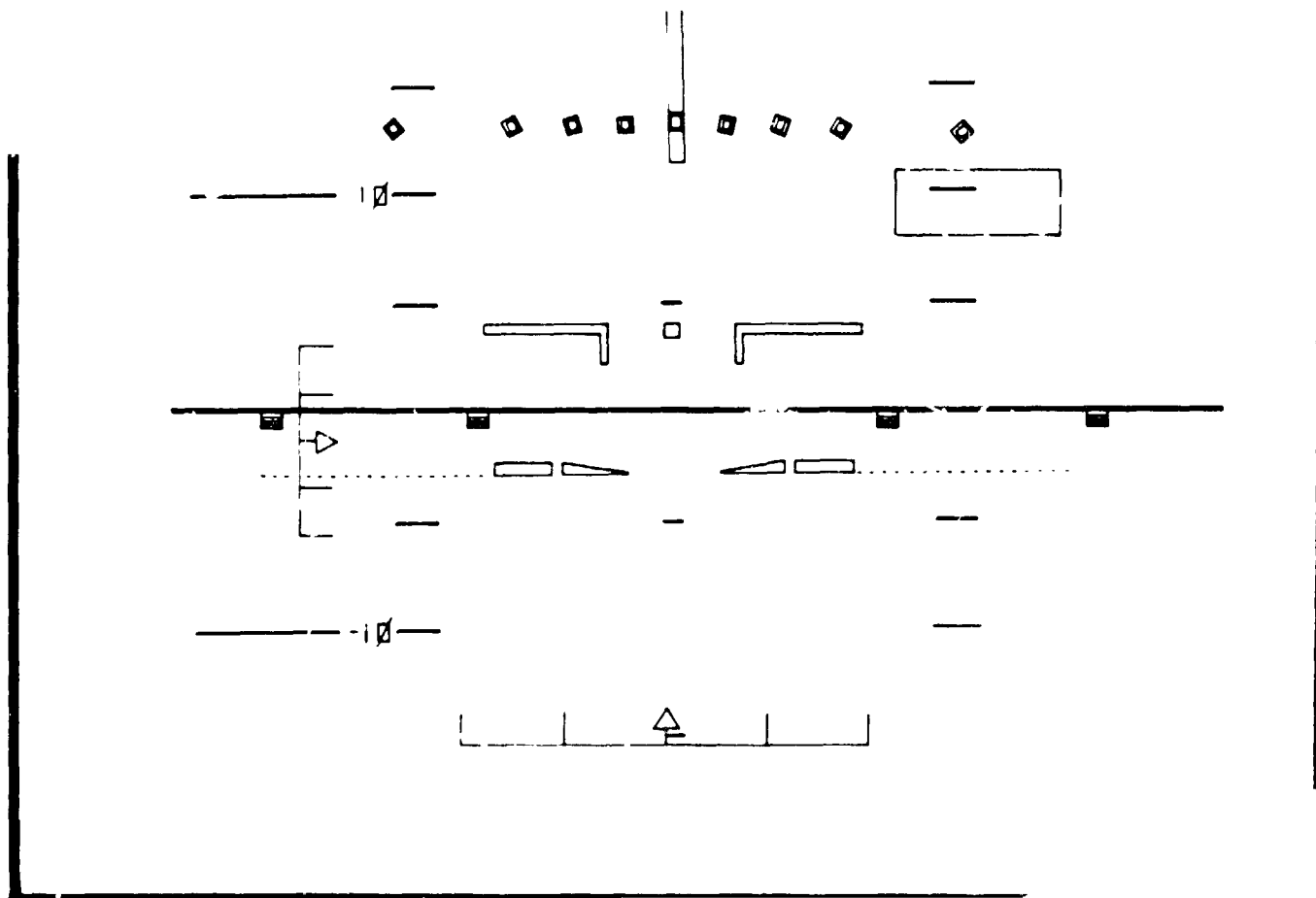
The flight path acceleration bars are located to the left and right of the flight path angle symbol.



Displacement of the flight path acceleration bars above the flight path wedges represents a positive acceleration of the aircraft along its flight path.



Displacement below the wedges represents a deceleration along the flight path. You will see this happen each time flaps are put down or speed brakes are used



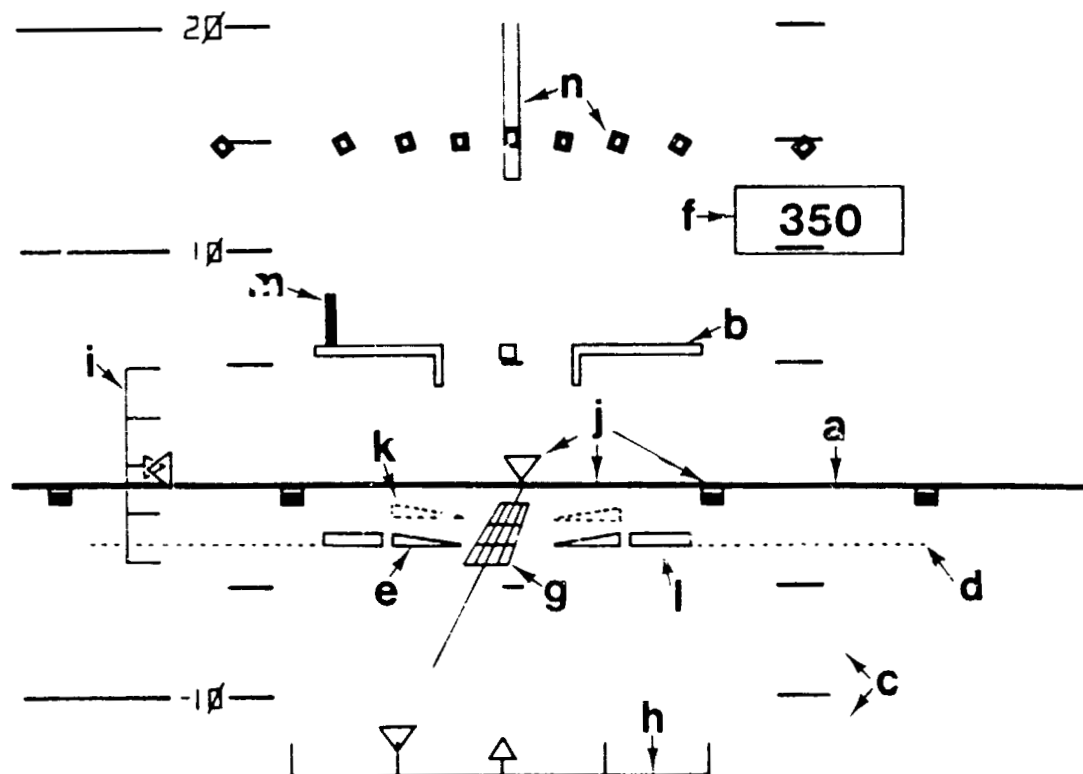
When flight path angle wedges are aligned with flight path acceleration, the acceleration along the flight path is zero and the aircraft is maintaining a constant airspeed and vertical speed.

Auto Throttle will compensate for pitch input changes to flight path angle.

Suppose you wish to change the flight path angle to another value by changing pitch input. The throttle will automatically adjust to maintain alignment of the Flight Path Angle and Flight Path Acceleration symbols.

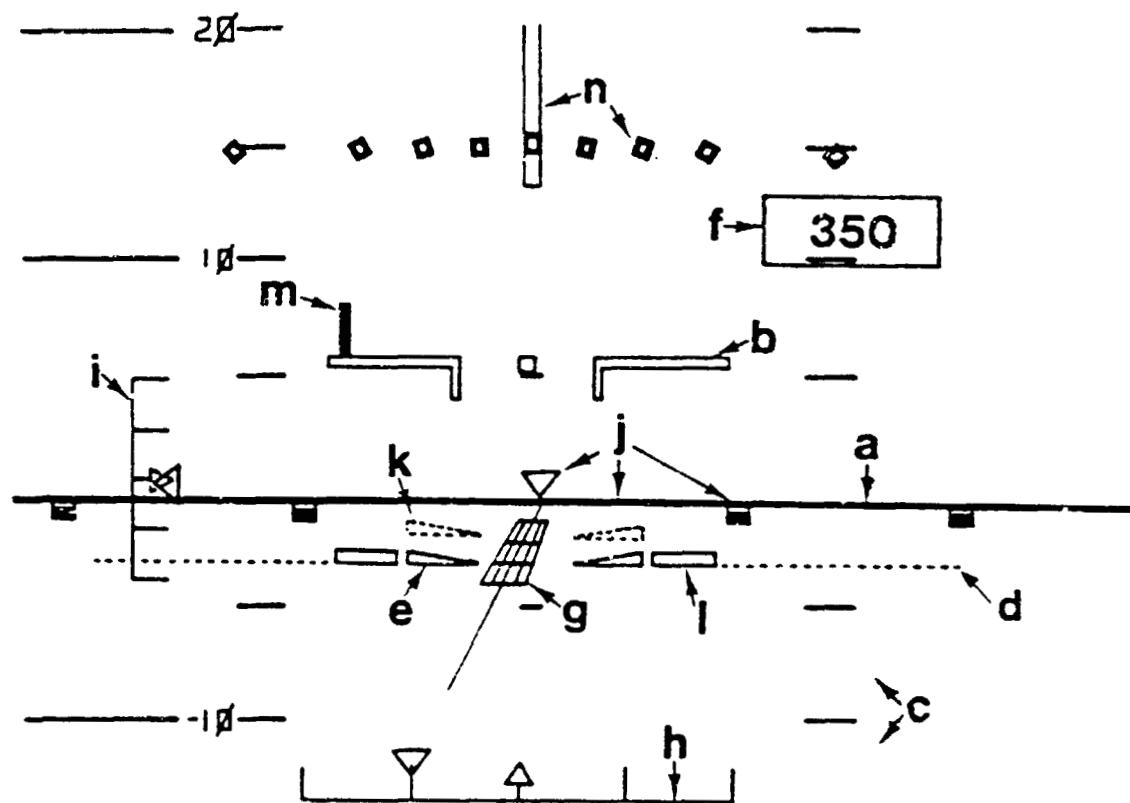
QUIZ

This completes this lesson on familiarization and interpretation of the EADI and its symbols. Now, here's a final review quiz.



Identify each symbol on your answer sheet. After you've identified all of them, re-start the tape.

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Here they are correctly identified:

- a. Horizon line
- b. Airplane Symbol
- c. Pitch Scale
- d. Pitch reference line
- e. Flight path angle wedges
- f. Radar altitude
- g. Runway perspective and extended centerline
- h. Localizer scale and pointer
- i. Glide slope scale and pointer
- j. Track angle scale and pointer
- k. Flight path angle reference wedges
- l. Flight path acceleration bars
- m. Speed error bar
- n. Bank angle scale and pointer

If you did not identify all the symbols correctly, it is suggested that you review the appropriate section of this lesson.

Understanding of the EADI is essential.

As we said before, if you did not correctly identify each symbol you should review the appropriate section of this lesson. Absolute knowledge of the symbols and their function is essential before you move to the next lesson in this series, which will deal with practical flight applications of the EADI. One other tip — even if you correctly answered all the quizzes, it wouldn't be a bad idea for you to review this lesson at a later date. It has the same value as re-current training.

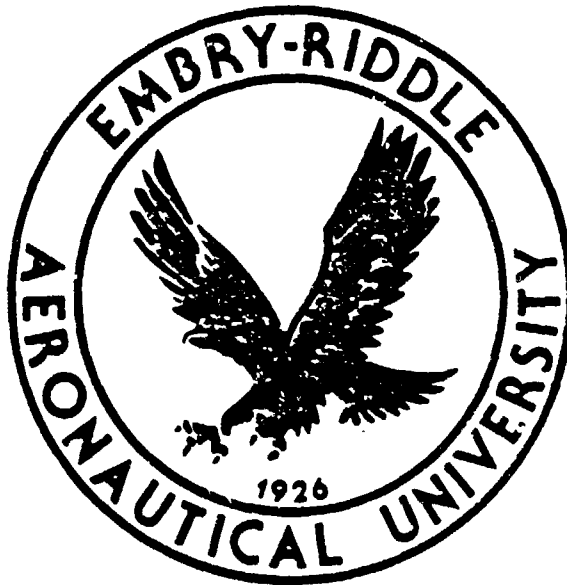
STOP, and take a break

And finally, it is not suggested that you go directly to the next lesson at this time, as learning fatigue would occur and you would not get full benefit from the next lesson. However, if you must proceed, stop now and take a short break. This will help you overcome learning fatigue and assist your comprehension,...

NASA

June 1979

of the Electronic Attitude Director Indicator, one of the electronic display systems currently being evaluated in the Terminal Configured Vehicle Program at the National Aeronautics and Space Administration's Langley Research Center. Technical guidance was provided by Langley's Analysis and Simulation Branch.



This program was produced by Embry-Riddle Aeronautical University.